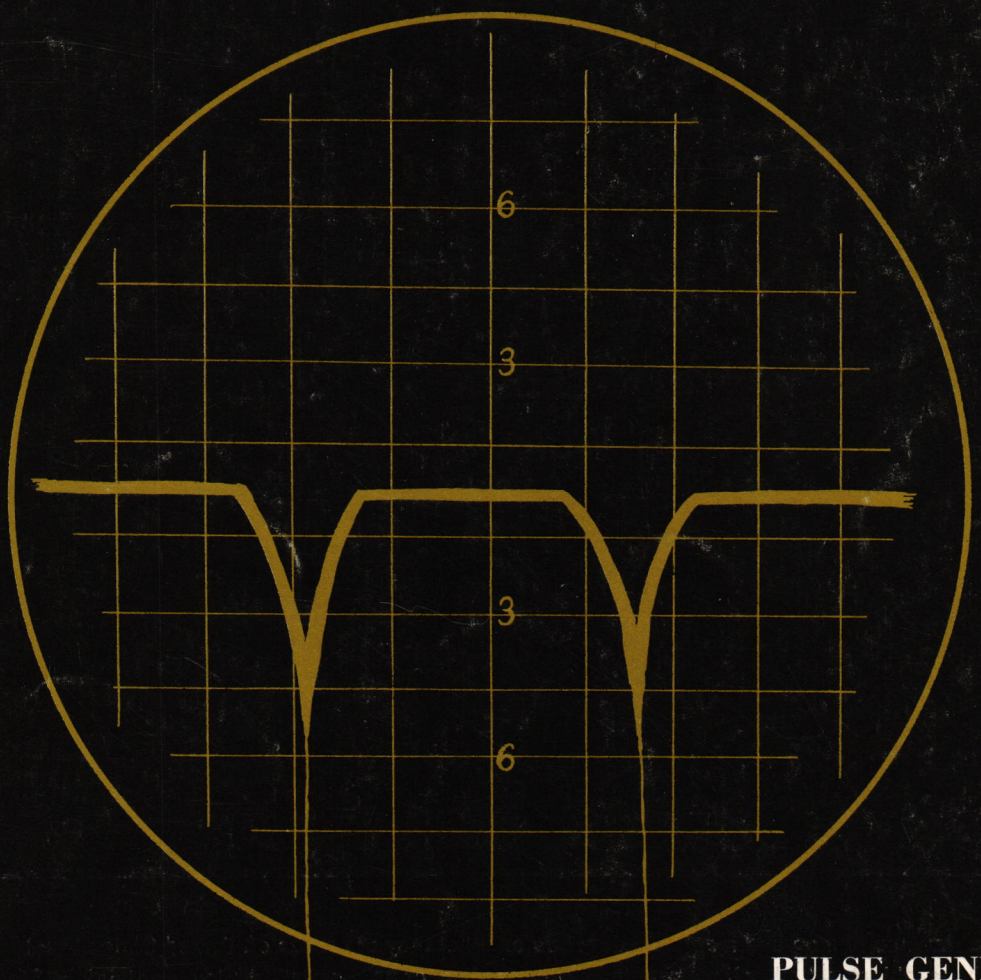
the Mechelectiv

VOL. 18 APRIL, 1960 No. 5

THE GEORGE WASHINGTON UNIVERSITY — SCHOOL OF ENGINEERING



PULSE GENERATOR OUTPUT

See Page 8

THE GEORGE WASHINGTON UNIVERSITY

APRIL, 1960

Under fire, the performance of men and machines depends on what they are made of. United States Steel makes the materials for the machines, whether it's a very tough armor plate, or heat-resistant alloy, or Stainless Steels.

You might be interested in some of the USS steels developed specifically for aircraft and missiles: USS Strux, an alloy steel with close to 300,000 psi tensile strength primarily for aircraft landing gears; USS Airsteel X-200, an air-hardenable alloy steel with 230,000 psi yield strength for aircraft sheet and missile applications; USS 12MoV and USS 17-5 MnV Stainless Steels for high-speed aircraft and missiles; Stainless "W", a precipitation-hardenable Stainless Steel.

New special metals, new methods for making them, present an exciting challenge. Men willing to accept this challenge—civil, industrial, mechanical, metallurgical, ceramic, electrical or chemical engineers—have a future with United States Steel. For details, just send the coupon.

USS United States Steel

USS is a registered trademark

United States Steel Corporation
Personnel Division
525 William Penn Place
Pittsburgh 30, Pennsylvania

Please send me the booklet, "Paths of Opportunity."

Name _____

School _____

Address _____

City _____ **Zone** ____ **State** _____

IT'S LITERALLY ALL AROUND YOU!

The word *space* commonly represents the outer, airless regions of the universe. But there is quite another kind of "space" close at hand, a kind that will always challenge the genius of man.

This space can easily be measured. It is the space-dimension of cities and the distance between them . . . the kind of space found between mainland and offshore oil rig, between a tiny, otherwise inaccessible clearing and its supply base, between the site of a mountain crash and a waiting ambulance—above all, Sikorsky is concerned with the precious "spaceway" that currently exists between all earthbound places.

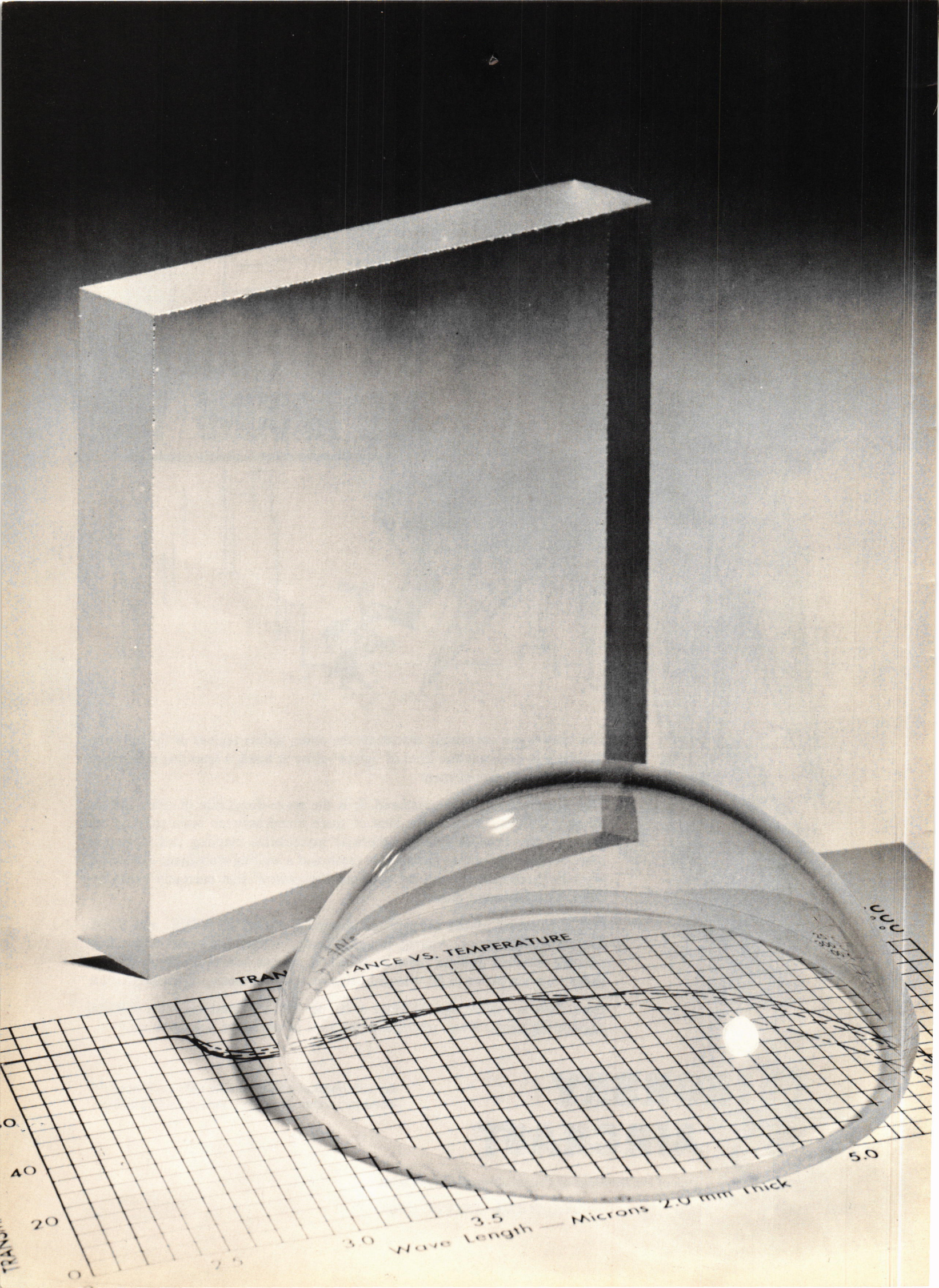
Our engineering efforts are directed toward a variety of VTOL and STOL aircraft configurations. Among earlier Sikorsky designs are some of the most versatile airborne vehicles now in existence; on our boards today are the vehicles that can prove to be tomorrow's most versatile means of transportation.

Here, then, is a space age challenge to be met with the finest and most practical engineering talent. Here, perhaps, is the kind of challenge *you* can meet.

SIKORSKY AIRCRAFT

One of the Divisions of United Aircraft Corporation

For information about careers with us, please address Mr. Richard L. Auten, Personnel Department.


TRANSMITTANCE VS. TEMPERATURE
40
20
0
2.5
3.0
3.5
5.0
Wave Length — Microns 2.0 mm Thick

EDITOR-IN-CHIEF
Bob Gerber

BOARD OF EDITORS
Don Baechler
Tom Miller
Nick Kopulos
Al Graps
Stan Tull

BUSINESS MANAGER
Jack Petrick

EDITORIAL STAFF

FEATURE WRITER
Moffette Tharpe

LAYOUT EDITOR
John Wolfgang

ART EDITORS
Fred Hood
John Howie

PHOTOGRAPHER
Jim Black

JOKES EDITOR
Herb Wilkinson

BUSINESS STAFF

ASST. BUS. MGR.
Ray Morales
Herb Wilkinson

CIRCULATION MANAGER
Arthur Macurdy

ADVERTISING MANAGER
Al Graps

OFFICE MANAGER
Dan Havens

Member
ENGINEERING
COLLEGE MAGAZINES
ASSOCIATED

Chairman
Prof. Stanley Stynes
Wayne Univ.

National Advertising
Representatives
Littell-Murray-Barnhill, Inc.
369 Lexington Ave.
New York 17, N. Y.

the Mechelecіv

VOL. 18 APRIL, 1960 No. 5

ARTICLES

IF I HAD ONE LAST LECTURE TO GIVE
Dr. Norman B. Ames 5

FORTY YEARS WITH DEACON AMES
Stan Tull 6

THE DESIGN OF A FREQUENCY-STABLE GENERATOR
Jack Nimetz and Ronald Grossman 8

THE MERCURY VAPOR LAMP—NEW STAR OF STREET LIGHTING
Frederick J. Gauvreau 12

FUNDAMENTALS OF UNDERGROUND CORROSION
Richard Beuttenmuller 22

DEPARTMENTS

GUEST EDITORIALS 4

MECH MISS 14

WHAT'S NEW 16

LETTERS TO THE EDITOR 26

ENGINEERING ADVANCES 28

THE BLACK BOX 32

ON THE COVER:

An oscilloscope display of the output from a pulse generator. The design of a pulse generator is the topic of the story starting on page 8.

Published at the George Washington University by direction of the Engineers' Council. Published six times during the school year in October, November, December, March, April, and May. Entered as second class matter March 6, 1951, at the Post Office at Washington, D. C., under the act of March 3, 1879. Address communications to Mecheleciv Magazine, Davis-Hodgkins House, George Washington University, Washington 6, D. C. or telephone STerling 3-0250, Extension 528.

Subscription Price: Two Dollars

CHANGE OF ADDRESS: Send your new address at least 30 days before the date of the issue with which it is to take effect.

Editorial Page

A Thing of Beauty

Mathematics, rightly viewed, possesses not only truth, but supreme beauty — a beauty cold and austere, like that of sculpture, without appeal to any part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show. The true spirit of delight, the exaltation, the sense of being more than man, which is the touchstone of the highest excellence, is to be found in mathematics as surely as in poetry. What is best in mathematics deserves to be learnt not only as a task, but to be assimilated as a part of daily thought, and brought again and again before the mind with ever-renewed encouragement. Real life is, to most men, a long second-best, a perpetual compromise between the ideal and the possible; but the world of pure reason knows no compromise, no practical limitations, no barrier to the creative activity embodying in splendid edifices the passionate aspiration after the perfect from which all great work springs. Remote from human passions, remote even from the pitiful facts of nature, the generations have gradually created an ordered cosmos, where pure thought can dwell in its natural home, and where one, at least, of our nobler impulses can escape from the dreary exile of the actual world.

—BERTRAND RUSSELL, *"Mysticism and Logic."*

Engineering Alumni Advice to Freshmen on Studying English

by *Herman A. Estrin*

Professor Estrin, author of over fifty professional articles, is Executive Associate of the Department at the Newark College of Engineering. His A.M. and Ed.D. are from Columbia.

What advice would you give a freshman concerning the study of English in an engineering curriculum? This question was asked of two hundred alumni of the Classes of 1949, 1950, and 1951 of Newark College of Engineering. They answered as follows:

1. Approach English as you would any task. Work as hard at it as you need to become proficient. English is governed by rules and laws as are all technical studies. Learn and use them.

2. Utilize every opportunity to write, and in writing, practice conveying ideas clearly and concisely.

3. Treat English at least as importantly as any technical course and get as broad and comprehensive an English background as possible.

4. Become proficient in expressing yourself on paper. Develop the habit of writing all decisions, since industry tries to avoid verbal orders.

5. Learn the fundamentals of grammar well. Learn how to present ideas, to put important things first, and to eliminate the irrelevant.

6. Learn to write technical papers and learn to read them. Learn how to organize and present a technical report verbally through use of charts and graphs. Above all, learn how to spell! Misspelled words create the same impression as gravy stains on a necktie.

7. Concentrate particularly in acquiring the ability to write clear, concise letters and articles. Master completely not only grammar forms but also rhetoric. Become thoroughly able to think and speak on your feet.

8. Treat English I as you would Physics I or Chemistry I. *The pen displaces the slide rule as an individual advances in engineering.*

9. Pay close attention to the assignments. Advancement in business (including greater remuneration) can be achieved only by people who can express their thoughts and desires in a manner that will make them be listened to by others. This can be accomplished only by speech or composition.

10. Use your teacher harshly as your critic. English is a subject as important as any of the rest, and you cannot afford the luxury of letting the teacher set the pace.

11. Take English, but study *communication.* This, more than any other quality which you may possess, will set the rate and extent of your professional advancement.

12. Learn sentence structure and write intelligently: I think that we should be made to read other men's compositions and reports to see how miserably most people write.

13. Do not consider English as a secondary subject. It can be more valuable than any technical course. More responsibilities given to a person in his job usually mean more administrative functions—resulting in less slide-rule work and greater need for effective English to communicate ideas and policy.

14. If you do not succeed in mastering Engineering, be certain to obtain a mastery of English. *For in the end it will be the one subject you will need more than any other during your lifetime.* ——

Reprinted from COLLEGE ENGLISH, Volume 21, November, 1959.

If I Had One Last Lecture to Give

MY LAST LECTURE

by Dr. Norman B. Ames

Late Professor of Electrical Engineering

When asked what he would discuss if suddenly informed that he coud give only one more lecture to his students, "Deacon" Ames responded with this article, originally printed in the April, 1959 issue of MECHELECIV.

The mere contemplation of my last meeting with students in the class-room stirs me with mixed emotions—that of relief from a routine that has dominated my life for many years, that of genuine loss through the termination of associations with "my boys", and that of responsibility for some word of encouragement to you to feel the significance of the work you shall do as engineers.

There have been many advances in engineering and engineering education during my time; there will be many more during your time. There will be increasing emphasis on theory; particularly in mathematics, physics, and chemistry; and engineering, as such, may suffer a loss of prestige. Science is the keynote in the frantic competition for supremacy and even survival. Leonardo da Vinci said: "Science gives certainty and science gives power. Those who rely on practice without science are like sailors without rudder or compass." This is particularly true in the "Space Age" today.

But sound and time-tested practices must not be discarded, especially those of engineering, and this is the responsibility of the engineer. Someone must remember that electric power is the lifeblood of industry in every developed nation of the world. "Electric power is an intangible translated into terms of flesh and blood. It activates the vast web of technology in which modern man finds himself."* Electric power depends upon the development of natural resources of coal, oil, gas, water, and fission fuels. Conservation of these resources is imperative if ours is to be a survivor nation, certainly until fusion is an accomplished fact.

There will be an increasing need for real sanity in the future frenzy. How silly it is to talk about traffic controls in outer space while imperfectly controlled traffic on the earth now kills thousands. And how foolish it is for a nation to kill itself with radio-active fallout while planning to kill an enemy.

The Russians early realized the need for technicians and began training them—about six to eight for each engineer. Plans in our country must be accelerated for the training of technicians so that engineers may be effectively used in critical work.

You have already been discouraged many times and will be discouraged many times more when problems, reports, and exams loom ahead of you. Having been a part-time student myself, I have a natural sympathy for the student who is willing to make a sacrifice to improve his or her mind while supporting himself and, perhaps, a family. Remember the adage, "no one ever failed but many gave up too soon." Remember too, the words of Hans Christian Oersted: "The Universe is a manifestation of an Infinite Reason, and the laws of nature are the thoughts of God."

A final word: Be diligent in your efforts, have faith in yourself and your fellowman, and pride in your profession.

"A tired old doctor died today, and a baby boy was born—

A little new soul that was pink and frail, and a soul that was gray and worn.

And halfway here and halfway there

On a white high hill of shining air—

They met and passed and paused to speak

In the flushed and hearty dawn.

The man looked down at the soft, small thing, with wise and weary eyes;

And the little chap stared back at him with startled, scared surmise,

And then he shook his downy head—

"I think I won't be born," he said;

"You are too gray and sad!" And he shrank from the pathway down the skies.

But the tired old doctor roused once more at the battle-cry of birth,

And there was memory in his look, of grief and toil and mirth,

"Go on!" he said, "It's good—and bad;

It's hard! Go on! It's yours my lad."

And he stood and urged him out of sight, down to the waiting earth."

Harold Francis Branch

*Connor, Cross, Evans and Tannebaum: "Electric Power and Social Policy"; Columbia University, 1951.

Forty Years With Deacon Ames . . .

Early in March the Engineering School suffered a great loss in the death of Dr. Norman Bruce Ames, Professor of Electrical Engineering and a member of the faculty for forty years. Professor Ames, or the "Deacon" as he was universally called, was an extraordinary man and a gifted professor. His personality and his technical ability were both important factors in shaping the school as we know it today and it is for this reason that we of Mecheleciv offer here a brief review of the Deacon's long relationship with the School.

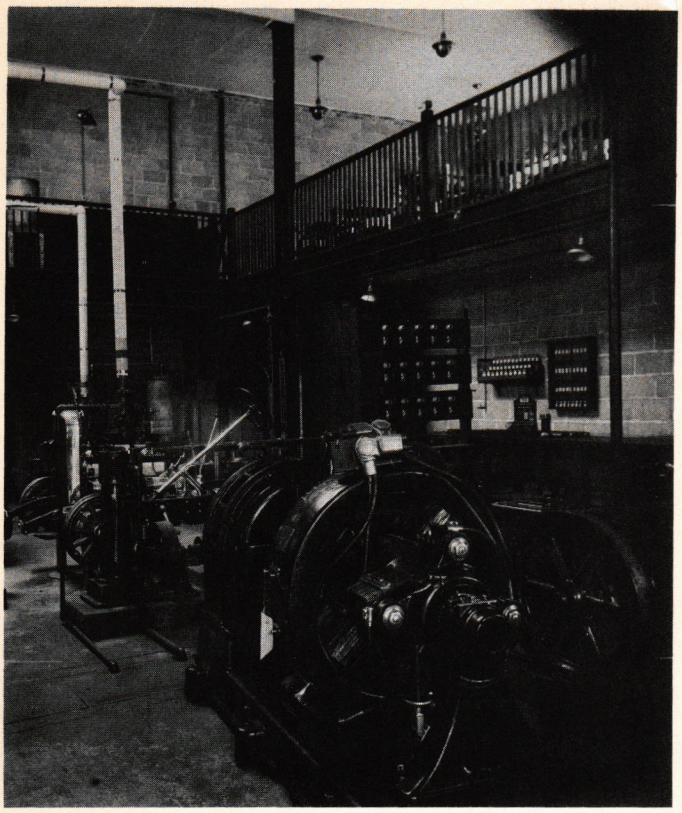
Professor Cruikshanks remembers the day back in the spring of 1920, when the Engineering School was located (with most of the rest of the University) in the old Lisner Hall at 2023 G St., in a building that had just recently been converted from a girl's school named St. Roses Academy, when the dean announced that he had found a new man who would be available to work full time in the Electrical Engineering Department. That man was Deacon Ames, then only 24 years old, but already the holder of degrees from Mississippi State, M.I.T., Harvard, and GWU. Those early days were a struggle. There was little money available for equipment and the Deacon solicited the large manufacturers of electrical equipment for gifts of used apparatus, which he then installed. Maintenance was a problem, too, and the Deacon spent many long hours servic ing these machines to keep them in top shape.

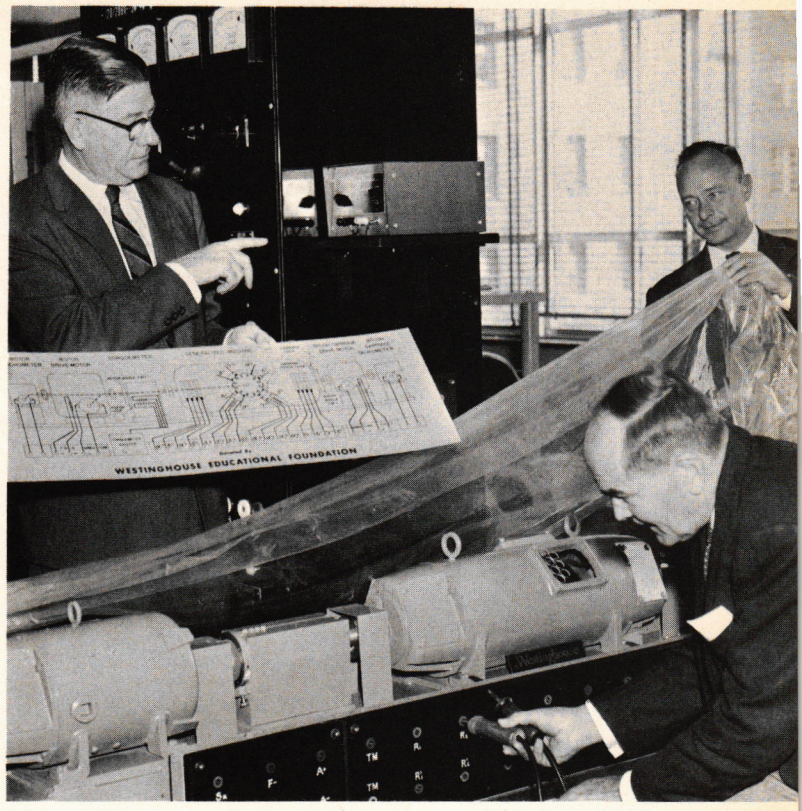
The curriculum for an EE in those days was built entirely around power. We went to the library recently and dug out an old catalog, for the year 1928, and looked over the EE curriculum. The first EE course was offered in the junior year. EE 2, 4 consisted of "Direct Current Theory and Machinery, with Laboratory" for 10 hours credit; lecturer: Ames. The senior year included 25 hours of EE courses with the following titles: Alternating Currents, Electrical Distribution, Elements of Transmission, Electrical Engineering, Hydroelectric Stations, Electric Railways, Electrical Illumination, and Design. Professor Ames' name was beside many of them.

The Engineering School by then had moved to Samson Hall. Professor Ames had been promoted to Executive Officer of the EE Department, and electronics was beginning to come of age. The Deacon had a real battle on his hands when he tried to install the first electronics course in his curriculum. The Physics department argued that electronics was their bailiwick and that the Engineering School should keep hands off. Needless to say, the Deacon had his way. Soon there was a need for expansion, and some classes were moved over to Corcoran Hall.

In 1940, with much of the world at war, Professor Ames requested and received a year's leave from the University to do special work in pilot training for the War Department. He became the Coordinator of the Civilian Pilot Training Program during this period. There followed a semester back at his job at the University full time and then, in February, 1942, he joined the U. S. Army as a Major, his second time in uniform, having served as a second lieutenant in France and Germany in WWI. But the uniform could not keep him from the classroom and he found time to teach evening courses here until he was again ordered overseas. A letter written to a friend from the vicinity of Naples during early 1945 shows that Colonel Ames was still very much a part of the University and was already offering suggestions as to curriculum changes that might best accommodate the needs of G.I.'s returning under the G.I. bill.

In February of 1946 he returned to the University which was at that time filled to overflow with G.I.'s. The demand on the teaching staff was so great that the resources of the





The old and the new. Left: one of the early machines installed in Samson Hall. Right: the Deacon inspects the new Westinghouse generalized machine.

school were concentrated on obtaining sufficient instructors to meet the immediate needs and there was no time to work at curriculum improvements. At this time the Deacon was the only full-time professor on the staff of the EE department.

By now it was "Deacon Ames" to faculty and students alike. The Deacon's energy and enthusiasm had carried him to the Presidency of the Montgomery County Charter Board in which position he led the fight for home rule in that community; to the National Regency of Theta Tau; to the position of Director and Secretary of the engineering firm, Murphy & Ames, Inc.; and to active membership in a host of activities which included the AIEE, IRE, Sigma Tau, Delta Tau Delta, Omicron Delta Kappa, and many others. He was cited by the GWU Alumni Association in 1946 for his "devoted service to the faculty and students of the School of Engineering."

The Deacon's own education never ended. Eventually he acquired seven degrees. By attending summer on-the-job training assignments with G.E. he was kept up to date with information on new developments in the field of electric power, thus closing the gap between industry and the school. Then, in March of 1956, came an award of a Fulbright lectureship in Electrical Engineering at the University of Ceylon.

When he returned the new Tompkins Hall was in use and there was electrical machinery to be placed and connected and larger-than-ever student enrollment.

Last year when Westinghouse Electric Corporation recognized the "excellence of the engineering curriculum" at the University by presenting a citation and a generalized machine capable of simulating the motions of many motors simultaneously, the machine arrived disassembled. Professor Ames assembled the machine before the Westinghouse representative arrived, and assembled it in such a manner as to greatly increase its versatility. Westinghouse then passed this method on to other users of the machine.

By the year 1960 the world of electrical engineering had come a long way from the rotating machines of 1920. The School of Engineering had kept pace, but some felt that things were now beginning to move even too fast for the Deacon. There were so many new things to be learned, and the Deacon was 64. Who could say for sure which of the new developments was progress, and which a worthless gadget? The Deacon was attending the IRE meeting a couple of months ago and the speaker had been describing a new thermoelectric device for generating power. Much of his talk was highly theoretical and when in conclusion he began discussing the many practical problems still in the way, the Deacon was heard to say, "they'd better not close down the Benning Plant yet."

At the time of the Deacon's death, Theta Tau was scheduling a giant testimonial and banquet to be given in his honor. Word was sent out to his fraternity brothers and former students around the country. Those who could not attend sent cards or letters and these were placed in a large scrapbook to be presented to him at the banquet. Many friends arrived from out of town to honor the Deacon and then received word of his death.

The loss to the University was more than academic. Students who came to the Deacon over the years for help, either in scholastic or personal matters, were never disappointed. We wish he could have made that testimonial dinner.

The Design of a Frequency-Stable Pulse Generator

RONALD GROSSMAN, E.E. '60

JACK NIMETZ, E.E. '60

The David Taylor Basin has recently acquired a Universal Computer Format Translator. This Translator enables one to change from one computer format to another; for example, from IBM 704 coding to Univac I coding. The translator also changes analog information into digital information; that is, analog or voltage representations of certain functions are translated into a digital form. In order to sample this analog information at discrete time periods, an external time generator is necessary. This generator must be capable of producing negative pulses at the precise frequencies of 500, 1000, 1500, 2000, 2500, and 3000 cycles per second. A pulse wdith of 15 microseconds and an amplitude of at least 1 volt is desired. The following is an account of the step by step procedure we used to design a generator to meet the above requirements. It is our intention to demonstrate to the reader a practical approach to the design of an electronic unit.

The general design of the unit is shown in figure 1. The most important consideration in designing the pulse generator was frequency stability, since each analog sample is to be separated by exact time intervals. Therefore the master clock which generated the pulses had to be very stable; i.e., the clock had to be relatively independent of circuit environmental conditions such as temperature and humidity. A self-excited oscillator was eliminated, therefore, since changes in temperature and humidity change the values of the circuit components which directly control the resonant frequency of the oscillator. The resonant frequency of a crystal, however, is effectively independent of circuit environmental conditions. A crystal controlled oscillator circuit was chosen, therefore, as the master clock.

As specified above, frequencies of 500 to 3000 cycles/sec in 500 cycle/sec steps are required. However, no commercial crystals are available at these low frequencies. Therefore, in order to obtain the benefits of crystal controlled oscillators, the beat frequency principle was used; i.e., two high frequencies were mixed and their difference was extracted. For example, the required frequency of 1.5 kc/sec was obtained by mixing together frequencies of 200.00 kc/sec and 201.50 kc/sec.

The output from the mixer, now a low frequency sine wave (see figure 2) was then fed into a clipper-shaper circuit where grid limiting cut off a portion of each positive half cycle. (See figure 3.) The output waveform (see figure 4) had a clipped negative portion because of plate current cutoff and a "squared-off" positive portion because of plate current saturation. In addition the amplification through the tube had increased the slopes of the signal so that, effectively, the sine wave was shaped approximately into the form of a square wave.

Next the wave was differentiated by an electrical differentiator. This is a configuration of a resistor and a capacitor such that the output voltage is a function of the slope of the input voltage at any time. This differeniator produced positive and negative spikes resulting from the positive and negative slopes of the approximate square wave. Since only negative pulses were required, the positive pulses were clipped by a diode connected in parallel with the differentiator.

The resulting negative pulses (see figure 5) were fed through a relatively long line to a low impedance load (the input of a transistor flip-flop). It was desired, therefore, that the output of the generator have an impedance which is relatively low. For this reason the generator was terminated with a cathode follower.

Now that the general design has been discussed, a more detailed description of the design problems encountered on each circuit follows. You will see that the emphasis is placed on practical engineering principles, rather than on

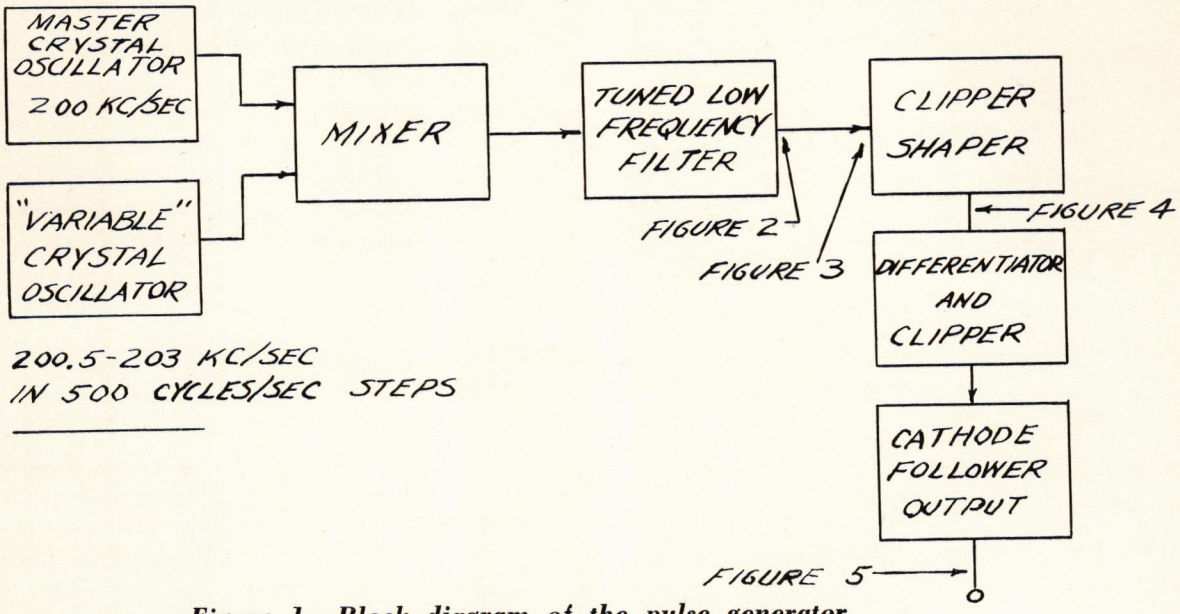


Figure 1—Block diagram of the pulse generator.

the mathematical derivations of the properties of each circuit. That is, we are concerned here with a technique involved in combining well-known "building blocks" to produce a unit that may be used to meet new requirements. As explained above, crystal oscillator circuits must be utilized to produce the precision characteristics desired. Also explained is the beat frequency principle, which must be employed with crystal oscillators in order to obtain a frequency on the order of magnitude of 1 kc/sec. The crystals selected for the pulse generator were type F-13 made by the International Crystal Manufacturing Company. The specifications for the crystal are given below.

Temperature tolerance: 0.015% (—40C to +70C)
Drive level: not to exceed one millivolt.
Calibration tolerance: guaranteed to tune zero frequency in recommended circuit.

Using the International Crystal Manufacturing Company F-13 crystal, the following circuit is recommended for a 32 mmf crystal load.

The frequency of the master crystal oscillator was selected at 200.00 kc. In order to obtain one of the desired frequencies, say 1.5 kc, a 201.50 kc oscillator was beat with the master oscillator. It was desired that the unit be capable of supplying negative pulses at the precise frequencies of 0.50 kc, 1.00 kc, 1.50 kc, 2.00 kc, 2.50 kc and 3.00 kc. Thus in order to obtain one of the desired frequencies, provisions had to be made to switch in the crystal which will produce this frequency when beat with the 200 kc oscillator. A two-pole six-position ganged switching design was used. (See oscillator stage of figure 10.) Each ceramic trimmer (50 mmf) is used to adjust the oscillator to the proper crystal center frequency.

The operating voltage of the crystal oscillators is 210 volts. In order to insure a constant supply voltage of 210 volts to the plates and screens of the oscillators, two 105 volt OB2 regulator tubes were used. Since a 300 volt supply was used with the generator, it was necessary to insert a

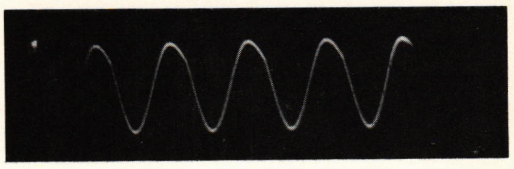


Figure 2

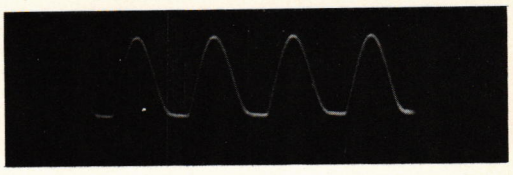


Figure 3

Figure 4

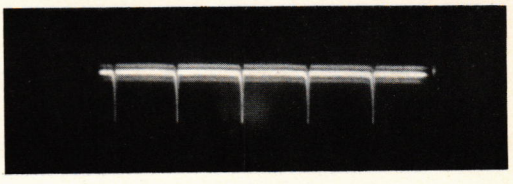


Figure 5

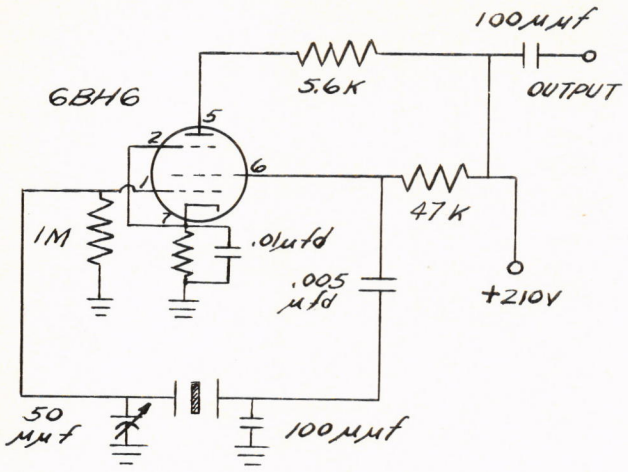


Figure 6

series dropping resistor R. This resistance limited the voltage to just the amount necessary to cause the regulator tubes to ignite. The currents drawn through the dropping resistor R were measured to be:

$I_{osc} = 30$ ma.
$I_{reg\ idle} = 15$ ma. (assumed quiescent current)

The total current through the resistor R is:

$I = 15 + 2(30) = 75$ ma

Since a minimum of 220 volts is required to fire the regulator tubes, less than an 80 volt drop is desired across R.

$R = E/I = 80/75 = 1.07K$
$P = I^2R = (075)^2(1000) = 5.6$ watts

A 10 watt resistor will dissipate the power safely without becoming excessively hot.

Therefore a 10 watt, 1K ohm resistor was chosen. Since the oscillators were operating in the class C region, the output voltage appeared as a distorted, rectified sine wave. (See figure 7.) In order to obtain a pure sine wave, the grid resistor was reduced to 33K and a parallel resonant tank circuit was added to the output of each oscillator. It was assumed that these measures would furnish the missing part of the fundamental frequency and would reduce the total harmonic content. An inductor of 1 mh was chosen for the tank circuit. The capacitance, then, at 200 kc/sec is $C = 1/L\ (2\pi f)^2 = 620$ mmf.

While other combinations of L and C would resonate at the same frequency, these values were chosen so that the bandwidth of the tank circuit would be 3.00 kc (200,00 kc to 203.00 kc). The ratio determines the selectivity which the tank circuit offers; therefore the circuit Q must have a value which produces the required bandwidth. The Q of this combination of L and C was measured on the General Impedance Bridge, and was found to be approximately 40. The approximate bandwidth, therefore, was

$$\frac{f}{Q} = \frac{200}{40} = 5 \text{ kc/sec}$$

Since a maximum bandwidth of 3.0 kc was required, for all practical purposes, the tank was resonant at any of the frequencies of the "variable" crystal oscillator.

After the tank circuit was wired to the output of the oscillator, a 47 volt peak-to-peak sine wave was observed across the LC combination. Although the sine wave was essentially free from harmonics, the positive slope was slightly greater than the negative slope. (See figure 2.) This characteristic was used to our advantage in a later stage. A schematic diagram of the first stage is shown in the first part of figure 10.

The outputs from the crystal oscillator stages were now ready to be mixed. It was decided to use a heptode tube, since it was desired to mix the two signals by modulating a common electron stream. A 6BE6 tube which is normally used for frequency conversion was selected.

In order for the output from the mixer to be undistorted, the following operating conditions were imposed (these values were obtained from the GE Tube Manual):

$E_b = 250$ volts	$R_{g1} = 20.0$ K
$E_{sg} = 100$ volts	$I_b = 2.9$ ma
$E_{c3} = -1.5$ volts	$I_{sg} = 6.8$ ma
$E_{c1} = 10$ volts, RMS	$I_{g1} = 0.5$ ma

From the given data, grid no. 1 required 10 volts RMS (or a peak-to-peak sine wave value of 28.8 volts). Since 47 volts peak-to-peak was available, a voltage divider was necessary in order to reduce the output voltage to the required 28.8 p-p volts. The equation for the voltage divider are as follows:

$$28/47 = R_2/R_1 + R_2$$
or
$$R_1/R_2 = 19/28$$

therefore $R_1 = 20K$; $R_2 = 30K$

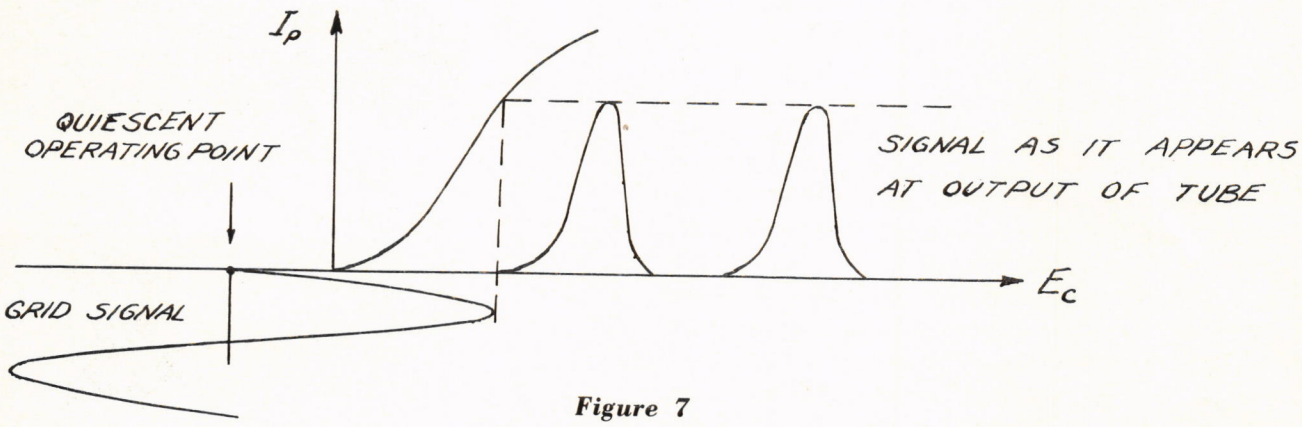


Figure 7

With these resistance values a 10 volt RMS signal appeared at grid no. 1 as recommended by the tube manual. All coupling capacitors used so far have been 100 mmf. At 200.00 Kcs. the capacitive reactance was low enough to pass AC signals without excessive voltage drop.

Since the tube manual stated that grid no. 3 operates at —1.5 volts, it was decided to used a grid resistor of 35K. With this value of grid resistance and a bias of —1.5 volts the third grid will draw 0.045 ma. This is below the maximum grid current as stated in the tube manual. When the 6BE6 is used as a frequency converter, grid no. 3 receives its grid bias from the AVC line; however in our application no fixed power supply was used to give this value of bias. It was decided instead to use a variable voltage divider (a potentiometer). The potentiometer was adjusted until just enough voltage was applied across the 33K resistor (and of course across the grid no. 3) to cause the grid to draw 0.045 ma. Thus, with this value of grid current, —1.5 volts was developed at grid no. 3. (See the mixer stage of figure 10.) The coupling capacitors allowed the AC signals to pass while the DC plate and grid voltages were blocked.

The screen grid was designed to operate at 100 volts. Available was a 300 volt power supply. Therefore a dropping resistor was used to drop the voltage to the 100 volts desired. R=E/I=(300—100)/6.8=29K. With a nominal value of 33K, the power dissipation is below ½ watt; therefore a ½ watt resistor was selected. The screen grid was bypassed to ground to prevent an AC variations from appearing at this grid.

Now that the proper operating conditions on the tube had been imposed the signals were properly mixed. In order to extract the difference frequency a parallel LC circuit was tuned to resonate at this desired frequency. The tank circuit filtered out to ground through the power supply all frequencies except this difference beat frequency. In order that the filter be adjustable, a UTC HVC-7 variable inductor was selected (0.5h to 1.5h). Since more than one frequency was desired in the final unit, a number of resonant tanks were used; each was inserted by a switching system. (See figure 10.)

A .01μf capacitor was used to by-pass the bottom of the tank to ground. This prevented the inductance of the power wiring to be added to the tank inductance. The capacitor effectively shorted the bottom of the tank to ground as far as AC was concerned but served as an open circuit to DC.

The mixer stage was now complete; a low frequency sine wave had been obtained. (See figure 2.) Now the objective was to obtain a waveform which had a steep negative slope (see figure 4) so that when differentiated, sharp negative spikes would result (see figure 5). Therefore, the sine wave from the mixer had to be properly shaped. The amplitude of the sine wave was measured to be 280 volts p-p. This voltage was more than sufficient to drive a 6AU6 to both plate current saturation and plate current cutoff.

Because of the 180 degree phase-shift through the vacuum tube, a negative slope at the output of the clipper-shaper would be caused by a positive slope at the grid of the shaper. It was advantageous, therefore, to adjust the shaper bias to beyond cutoff so that only the positive portion of the input signal would be seen at the plate of the clipper-shaper stage. For a 6AU6 tube the following operating conditions were imposed: (from GE Tube Manual)

$I_{c2} = 4.3$ ma.
$I_b = 10.6$ ma.
$E_{c2} = 150$ volts
$E_b = 250$ volts

Since r_p was high, a high value of the plate load resistor was chosen (470K). This value was critical to the overall gain of the stage, but since gain was not an important consideration, any high value of plate load resistance could have been selected. The screen grid was designed to operate at 150 volts. It was computed that a 35K resistor would drop 150 volts of the supply voltage (300 volts) leaving the screen grid at a potential of 150 volts. To keep the screen at AC ground potential, a .01 uf bypass capacitor was used (see shaper stage of figure 10).

A high resistance was now needed to limit the grid current during the positive half cycle. During the negative half cycle the tube was beyond cutoff and therefore did not conduct. A grid resistance of 100K was chosen. The bias established at the grid due to grid current was measured to be —30 volts. The grid current was then limited to 0.30 ma (computed by Ohm's Law). This was below the maximum allowable value.

The coupling capacitor from the mixer plate to the clipper-shaper grid was chosen to be 0.5 uf. Its reactance at 1500 cycles was 4.7K ohms. This value of reactance was much less than the value of the grid resistance (100K); therefore very little of the input signal to the clipper-shaper was dropped across the coupling capacitor.

When the circuit was completed the output waveform was examined on a Hewlett Packard Oscilloscope. The observed waveform is shown in figure 4. Note that a steep negative slope has been obtained. An analysis of this waveform follows (see figure 8).

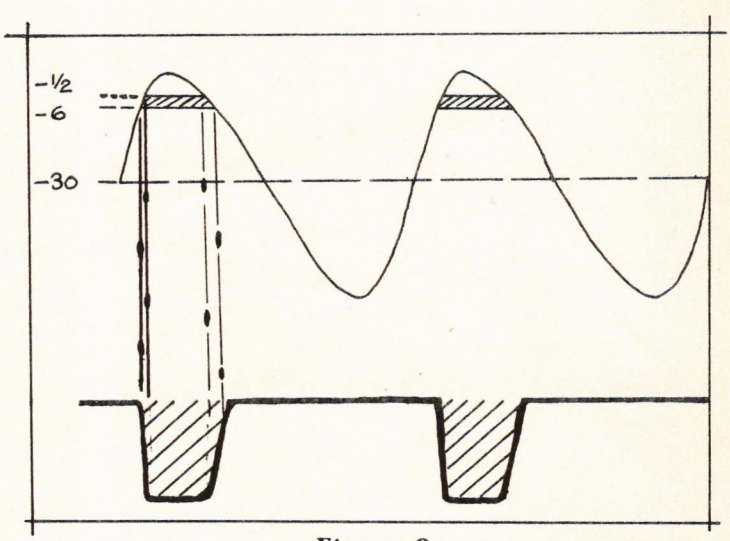


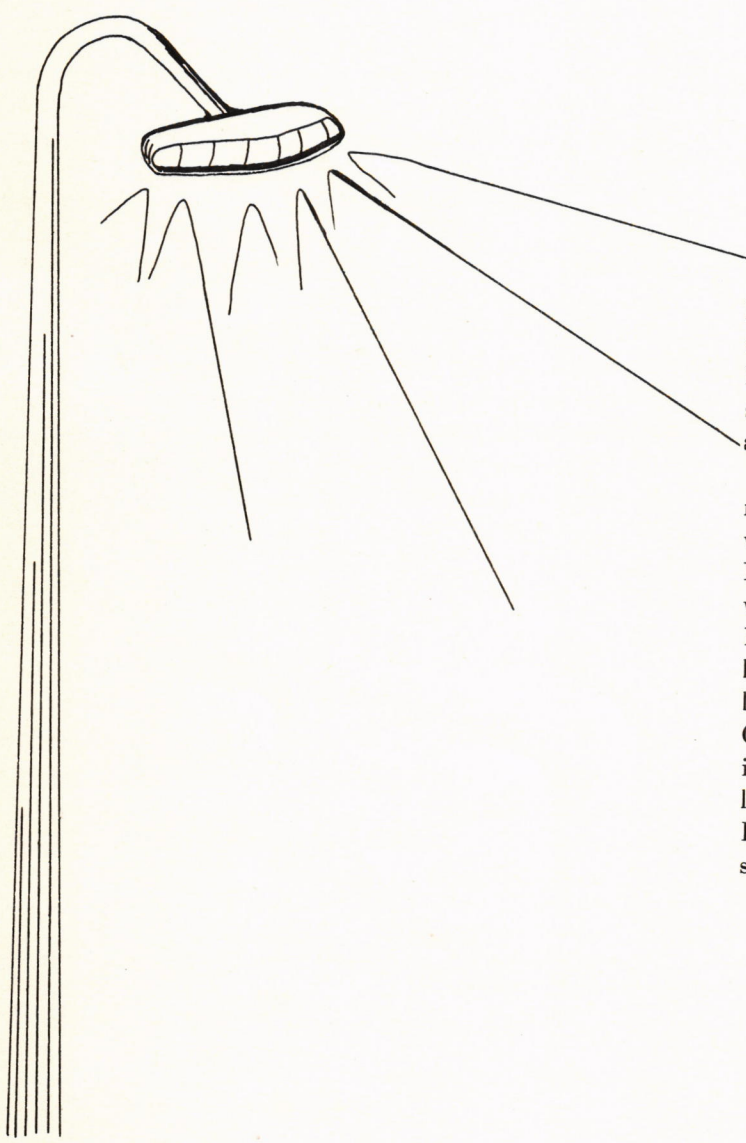
Figure 8

(Continued on Page 30)

The Mercury Vapor Lamp—

New Star of Street Lighting

by FREDERICK J. GAUVREAU, M.E. '61



In recent years more and more of our streets have been made almost as bright at night as they are during the day. The dark street with fear lurking in the shadows is being made a thing of the past by the new mercury vapor streetlight that gives a brilliant glare-free bluish light to anyplace where it is installed.

Mercury vapor lamps however, are not something brand new. The idea of passing an electric arc through mercury vapor and hence getting a useful glow goes back to around 1856. The ancestor of the modern mercury vapor lamp was invented by an American, Peter Cooper Hewitt, in 1901. Four hundred watt and smaller mercury vapor lamps were used in Great Britain and Europe for street lighting around 1930. In 1934 the Westinghouse Lamp Company introduced high intensity mercury vapor lamps in the United States. The first attempt at using these lamps for streetlighting in the United States was made in Denver, Colorado, in 1936.[1] These lights were not very satisfactory because at this time no luminaire (the fixture

in which the bulb is mounted) had been designed specifically for mercury vapor bulbs and as a result the control of the light was poor. Other drawbacks of these early lamps were the excessive bluishness of the light produced and the fact that the lamps could only be mounted in a vertical position. In 1938 an improved version was introdueed. This lamp used a higher pressure mercury vapor and as a result was thirty-three per cent more efficient, produced a much whiter light, and could be mounted in any position. In 1946 Westinghouse introduced a luminaire to go with this EH1 lamp. This was the first luminaire designed just for mercury vapor bulbs and was the first that permitted them to be operated in the more efficient horizontal position. The trend toward mercury vapor streetlighting started after this.

The operation of the mercury vapor lamp is quite simple. It works on the same principle as other gaseous discharge lamps (sodium vapor, fluorescent, and neon are examples of others); that is an electric current is passed thru a gas, exciting it and causing it to glow. There are two types of mercury vapor lamps; the low pressure and the high pressure. The first models used in streetlighting were low pressure ones using a pressure of one atmosphere and producing 16,000 lumens of light per 400 watt lamp.[2] The more modern lamps in service today use a pressure of two and one-half atmospheres. This high pressure is used to get greater efficiency and a more balanced light output from the higher wattage lamps now used.

The mercury vapor lamp itself is made up of two tubes, one inside the other. The inner tube contains the electrodes, mercury, and a small amount of argon gas to aid in starting the lamp. This inner tube is made of quartz in order to contain the high pressure and the arc. The glass outer tube serves as a heat-insulating jacket. The modern mercury vapor light bulb is not much larger than an incandescent lamp of the same wattage.

The biggest advantages of mercury vapor lights are that they operate best on alternating current and that have a high lumen per watt output,[3] approximately fifty lumens per watt of electricity used. Other advantages are that there is almost no glare from mercury vapor lights because they are not point sources, and that the high lumens per watt output means that fewer fixtures supply more light, while increasing the amount of light on the streets. In addition, mercury vapor lamps themselves have a much longer life span than comparable incandescent lamps, which means less frequent bulb replacement and hence lower maintenance cost.

Mercury vapor lamps have four main disadvantages. These are high initial expense per fixture, the necessity for having auxiliary equipment (referred to as the "ballast") to start each lamp, the need for expensive wiring in some installations to prevent the lamps from flickering, and the bluish color of the light they produce. The high initial cost is caused primarily by the ballast and other accessories needed to start and maintain the arc which produces the light. Mercury vapor costs range from a low of $478.84 per fixture in a small city with some wiring already present to around seven hundred to one-thousand dollars per fixture in a large metropolis.[4] The problem of the flickering lamps has been overcome by a new development called constant wattage ballast. This ballast adjusts to variations in the input voltage of either 100-130 volt lamps or 200-260 volt lamps.[5] This adjustment gives constant light and more reliable starting; in addition to saving the expense of the high voltage lines and transformers which used to be used to control this problem. The bluish color of mercury vapor light has been removed by coating the inside of the outer tube of the bulb with red fluorescing phosphors. These modified bulbs are available in four hundred, seven hundred, and one-thousand watt sizes; while regular mercury vapor bulbs are available in sizes from one-hundred to one-thousand watts.

Recently fluorescent lamps have been perfected for streetlighting use but they will probably not replace the mercury vapor lamps like the mercury vapor lamps are replacing incandescent lamps. The reason is that fluorescent lamps, except for tunnel lighting, offer no advantages over mercury vapor and they are at an esthetic disadvantage because their long tubular shape requires a luminaire that has been described as resembling a coffin.

As city and town budgets permit, more and more of our streets and shopping centers will be illuminated by this economical bluish light that can turn night into day.

---

[1] E. B. Karns, "How New Is Mercury Vapor Lighting?", *The Westinghouse Stimulighter*, p. 7 (March, 1949.).

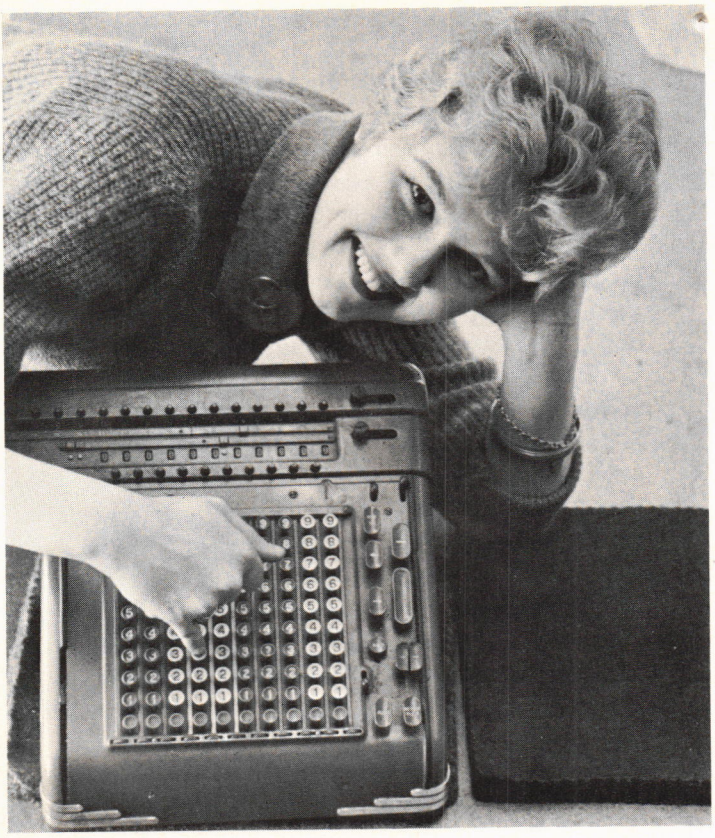
[2] W. B. Boast, *Illumination Engineering*, p. 140.

[3] J. O. Kraehenvuehl, *Electrical Illumination*, p. 155.

[4] D. J. Zucker, "Economics in Obtaining Vapor Lighting," *American City*, 71:156, 159 (September, 1956).

[5] H. A. Henry and D. D. Marvel, "Constant Wattage Ballast," *American City*, 71:153 (February, 1956).

Fred Gauvreau, E. E. '62, **is in the class of 1961 here at George Washington University. Actually, he plans to graduate in February, 1962. Now in his third year of the Air Force Reserve Officer Training Corps, he intends to spend two years in the Air Force after graduation and hopes that the experience gained there will be useful when he is employed as an electrical engineer. Fred was born in Washington and graduated from high school in Bethesda. Besides being in ROTC and attending school full-time, he is a member of Sigma Phi Epsilon, a social fraternity, and Sigma Tau, a national honorary engineering fraternity.**



MECH MISS . . .

This month, *Mechelecіv* ushers in spring with its April Mech Miss, Helene Harper. This blue-eyed blonde brings Spring to GW as this year's Cherry Tree Princess. Pretty Helene, a junior majoring in American Thought and Civilization, finds time after her work as Congressman Levering's secretary and her classes to participate in many of GW's activities. Among these, she sparks the cheerleaders as their co-captain, played in *Guys and Dolls* and *Damn Yankees*, and is a member of Delta Gamma Sorority.

Nineteen years old, Helene's greatest love is jazz, followed by dancing, swimming, tennis, sports cars, and Ocean City. She is well traveled, was born in Atlanta, Georgia, and has lived in Japan, Formosa, Florida, and Washington, D.C.

This 5 foot, 6 inch blonde weighs 115 pounds and swears her hair *is* natural blonde.

When asked what she thought about Engineers, Helene said that lots of the girls in her dorm wished they could meet more of them.

LOOK OUT MADISON HALL ! ! !

What's New?

Edited by NICK KOPULOS

SUBMINIATURE CIRCUIT BREAKER

A remote reset circuit breaker with a built-in light for use in low voltage electronic circuitry was introduced by Sylvania at the IRE convention in New York.

The new circuit protector is a subminiature device 1¼ inches long and ¼ inch in diameter. It is vacuum sealed in a glass envelope and contains a tungsten filament that becomes incandescent when the circuit is broken. With the circuit open, the filament produces sufficient light that acts as an indicating device and opens the breaker for as long as 100 hours.

The filament spans the contacts so that when the circuit is overloaded or shorted, the contacts of the breaker open and a fraction of the current is diverted to the filament. Excessive external heat will also actuate the breaker.

To reset the breaker, it is necessary only to open the circuit with a regular line switch and remove the short circuit until the circuit breaker rests itself. Usually, less than one minute is required for the resetting.

The current drawn by a tripped circuit breaker to illuminate the filament is approximately 200 milliamperes.

The new device has a bimetal thermal element consisting of two strips of different metals pressed together into a single, flat strip. When heated the bi-metal strip will curl, breaking the circuit because one type of metal expands more than the other. As it cools, the strip straightens and restores the circuit.

The circuit breaker can be operated at 6 to 24 volts AC/DC and will be available in a range that holds from one to five amps and which trips at double the amperage. At 78 degrees F, the tripping time ranges from five to forty seconds. External heat will trip the breakers at 200° F, making them useful in fire alarm systems, appliances and electronic equipment.

A NEW TELEVISION CAMERA

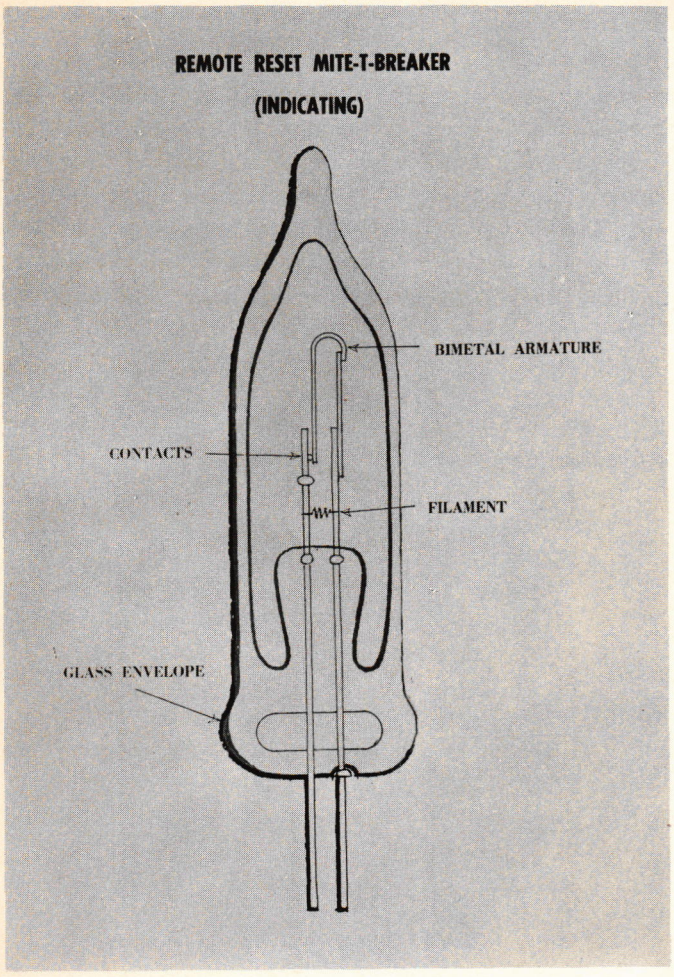
A television system consisting of a camera and camera control capable of being operated up to 2000 feet apart has been built to withstand weather, shock, vibration, noise, salt spray, dust, and other extremes of environment without an auxiliary protective housing. Weighing only 15 lbs., the camera is 16″ in length and 6-7/8″ in diameter. The camera control is 7″x19″ and weighs approximately 15 lbs.

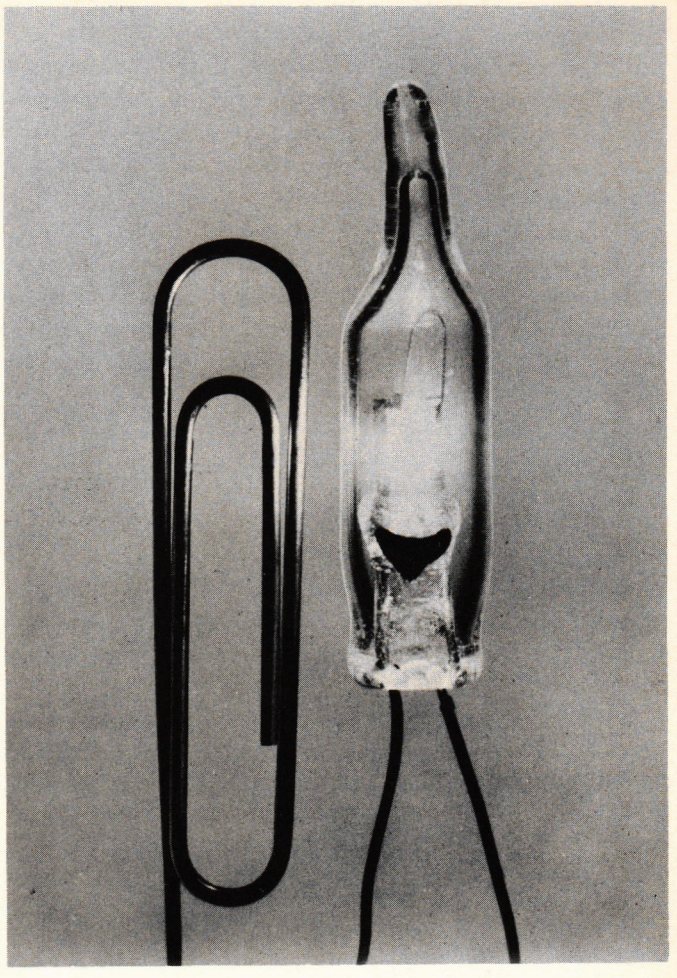
The system is totally transistorized, eliminating microphonics and erratic operation often caused by high acoustical noise levels, vibration and other environmental circumstances. It employs modular construction, using plug-in transistorized printed circuit modules, each representing a particular function of the camera. This construction provides maximum reliability and ease of maintenance.

Unique in this equipment is the provision for the selection of manual or automatic light level compensation. The automatic setting self-adjusts the camera circuits for high level changes over a range of 2000:1. Another feature is the provision of noise reduction circuits which represent a clean picture at low light levels. No additional equipment is required for pick-up of visual information.

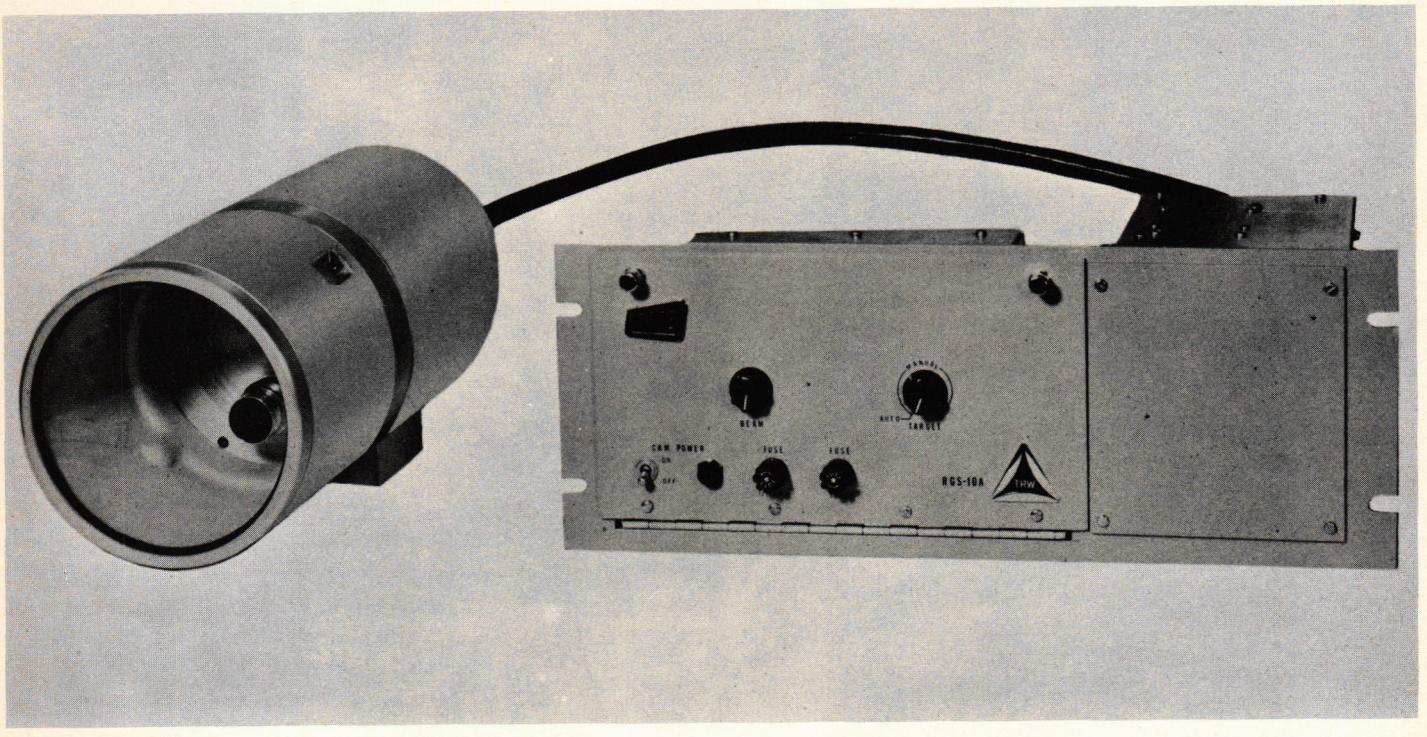
The system, developed by Dage Television Division of Thompson Ramo Wooldridge, Inc., draws only 15 watts, 115 VAC, 50-60 cycle or 400-cycle.

The camera will operate at from —20° F. to 160° F.; in noise levels of more than 185 db; and with no limit on altitude, making it ideal for space chamber and flight test applications where conditions of low pressure are encountered.





The subminiature circuit breaker with built-in indicator light.



This television camera and control unit are capable of operating in all environments with no additional housing.

ELECTRICAL MACHINERY LAB ON A TABLE TOP

Modern miniaturization techniques have condensed the electrical machinery lab to a table top. In addition they provide a wide measure of flexibility, so that students can study machines as system components as well as measuring the machine characteristics.

The new lab kit features compact 1/15 horsepower machines, including: dc machines (for use as motor, generator, or tachometer); wound rotor ac machines (for use as induction or synchronous motor, generator or synchro); squirrel cage ac motors as mechanical drive sources; miniature torque sensors for measuring magnitude and direction of static and dynamic torque between motors and loads.

All components are tapped for thumb-screw attachment to a grid plate supplied with the kit. Shafting is ¼″; it interconnects the components using shaft hangers with double bearing and flexible couplings. Power is supplied with dc, 400 cycle and 60 cycle power packs which are available, or power can be supplied from separate sources already in existence.

Supplemental equipment includes control transformers, potentiometers, demodulator, dc amplifier, and amplidyne. Conventional laboratory instruments are used for measurements.

NEW PREFIXES FOR UNITS

The National Bureau of Standards has decided to follow the recommendations of the International Committee on Weights and Measures to use new prefixes for denoting multiples and sub-multiples of units. The Committee adopted the prefixes at its meeting in Paris in the fall of 1958. In addition to the 8 numerical prefixes in common use, which are given in the table below, the Committee expanded the list by adding the 4 prefixes marked with an asterisk. Thus, for example, 10^{-12} farad is called 1 picofarad, and is abbreviated 1 pf.

Multiples and Sub-Multiples	Prefixes	Symbols
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera*	T
$1\ 000\ 000\ 000 = 10^{9}$	giga*	G
$1\ 000\ 000 = 10^{6}$	mega	M
$1\ 000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hetco	h
$10 = 10$	deka	dk
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	u
$0.000\ 000\ 001 = 10^{-9}$	nano*	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico*	p

Complete laboratory on a table top.

NEW ELECTRONIC "BRAIN" CELLS FIT IN THE EYE OF A NEEDLE

Basic building block for compact, electronic "thought savers" will serve you in your office, in defense – someday, in your home

● Today, science not only is working on labor-saving devices—but on *thought-saving* devices as well.

These "thought savers" are electronic computers —wonder-workers that free us from tedious mental work and are capable of astoundingly rapid computations. Naturally, the more *compact* these computers can be made, the more applications they can have. Not only in industry, defense and research—but in the office and ultimately in the home.

"Squeezing" exacting components

A big advance has recently been made by RCA research towards making these "thought savers" smaller than ever before, for broader than ever use.

Take, for example, the new "logic" circuit which actually fits in the eye of a needle. It is a new computer component developed by RCA.

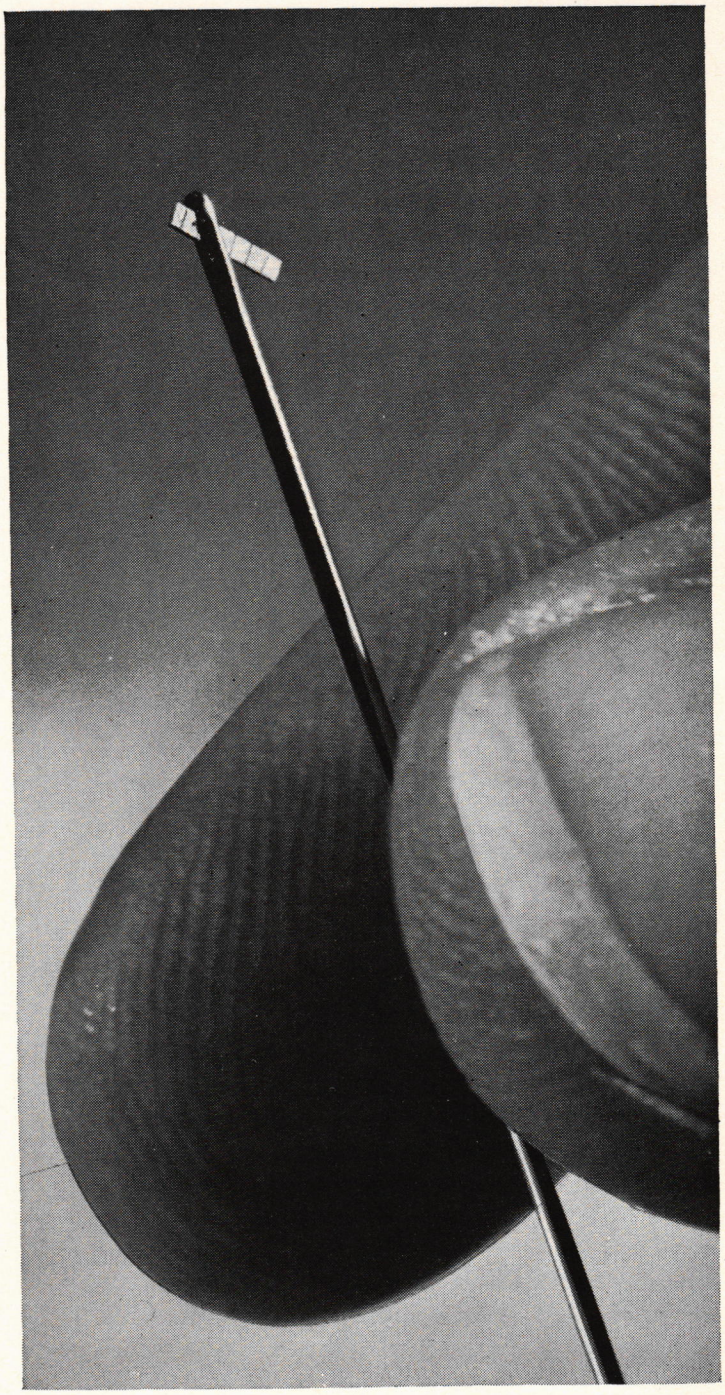
Today, the electronic functions of this micro-miniature device require a whole fistful of wires, resistors, transistors and condensers.

These tiny units will calculate, sort, "remember," and will control the flow of information in tomorrow's computers. Yet they are so small that 100,000,000 of them will fit into one cubic foot!

Cutting computers down to home size

This extreme reduction in size may mean that someday cigar-box-size electronic brains may help you in your home—programming your automatic appliances, and keeping track of household accounts.

Remarkable progress in micro-miniaturization is another step forward by RCA—leader in radio, television, in communications and in all electronics—for home, office, and nation.



Needle's eye holds electronic "brain" cells— Photograph shows how new RCA "logic" element can be contained in the eye of a sewing needle.

RADIO CORPORATION OF AMERICA
THE MOST TRUSTED NAME IN ELECTRONICS

WHAT'S NEW *(Continued from Page 18)*

STATISTICAL PLANNING OF PHYSICAL SCIENCE EXPERIMENTS

The National Bureau of Standards conducts a continuing research program on methodology in the planning and analysis of physical science experiments. Studies have resulted in the development of several new families of experiment designs which provide maximum information with a minimum number of measurements. Work has also been carried out on the tabulation of experiment designs to allow even the non-specialist to use these designs easily.

Two types of designs receive attention at the Bureau: fractional factorial designs, which are applicable to multi-factor experiments; and block designs, which are employed where measurements form homogeneous sub-sets. The fractional factorial designs allow the scientist to plan his experiment so that it will include only a fraction of the possible experimental combinations, thus providing savings in time and effort. The block designs balance out the effects of systematic errors and relieve the experimenter of much of the burden of reproducing on every occasion exact environmental conditions and exact experimental units.

Multi-factor or factorial designs

Experiments often involve several factors which jointly affect the material or process under investigation. For example, in a chemistry experiment, these factors may include temperature, time, concentration, and the presence or absence of a catalyst. Other things being equal, the smaller the number of factors, the fewer the difficulties encountered in the planning, analysis, and interpretation of the experiments. However, because of possible complex interdependencies among the effects of the various factors, the problems of analysis and interpretation become difficult even for experiments with a moderate number of factors.

Still another and perhaps more formidable problem is that as the number of factors increases, the number of different combinations of the factors increases exponentially. Often the experimenter has neither the resources nor time to investigate all possible combinations of the factors. Instead he desires to select a sub-set of all combinations which will serve as a basis for drawing conclusions about the effects of the various factors.

The Bureau's Statistical Engineering Laboratory has therefore tabulated a large number of fractional factorial experiment designs. Tables of fractional designs for experiments where each factor is varied at two conditions or at three conditions have been compiled with the partial support of the Army Chemical Corps and the Bureau of Ships, respectively. The latest work in this area has been the tabulation of fractional factorial designs for use when factors are varied both at two and three conditions. Unlike the other work, the theory for this mixed case was unknown. W. S. Connor, of the Statistical Engineering Laboratory, developed an extensive mathematical theory for these "mixed" fractionals, which served as a basis for the actual construction of the designs.

Block Design

The principle of "blocking" was developed in which experimental units which are close together are regarded as a "block." Here "close together" may mean on the same day, of the same materials, by the same operator, with the same apparatus, or whatever is appropriate in a given situation. The principle behind the analysis is to provide the desired comparisons using only the differences of measurements taken close together, that is, differences within a block. This eliminates extraneous variations caused by differences between methods or processes.

In physical, chemical, and engineering experimentation, a natural block is usually indicated by the problem itself. For example, the measurements taken during a single day or the readings taken with a particular thermometer form a natural block. Furthermore, the number of experimental units in a block is often not arbitrary, but fixed by the nature of the problem. The two sides of a thermocouple and the six or eight cylinders of a car engine are illustrations.

The Bureau's continuing research on experiment design has provided several news classes of incomplete block designs which are especially suited for use in the physical sciences. Examples are the chain block design developed by W. J. Youden and W. S. Connor of the Statistical Engineering Laboratory; the two-way elimination chain block design of J. Mandel of the Bureau's Organic and Fibrous Materials Laboratories; and experiment designs with block size two, which are especially useful in high precision work.

HONORS LIST
FALL SEMESTER 1960

The Faculty of the School of Engineering has provided for the recognition of meritorious scholastic achievement by the display and publication of an Honors List. The students whose names appear below have met all requirements established by the Faculty for this honor. On behalf of the Faculty, it is my pleasure to extend congratulations to these superior students.

As a matter of possible general interest, the Honors List contains ". . . in alphabetical order, the names of candidates for an undergraduate degree in engineering whose scholastic achievement satisfies all of the following requirements.

"a) The candidate's cumulative quality-point index is equal to or exceeds 3.00.

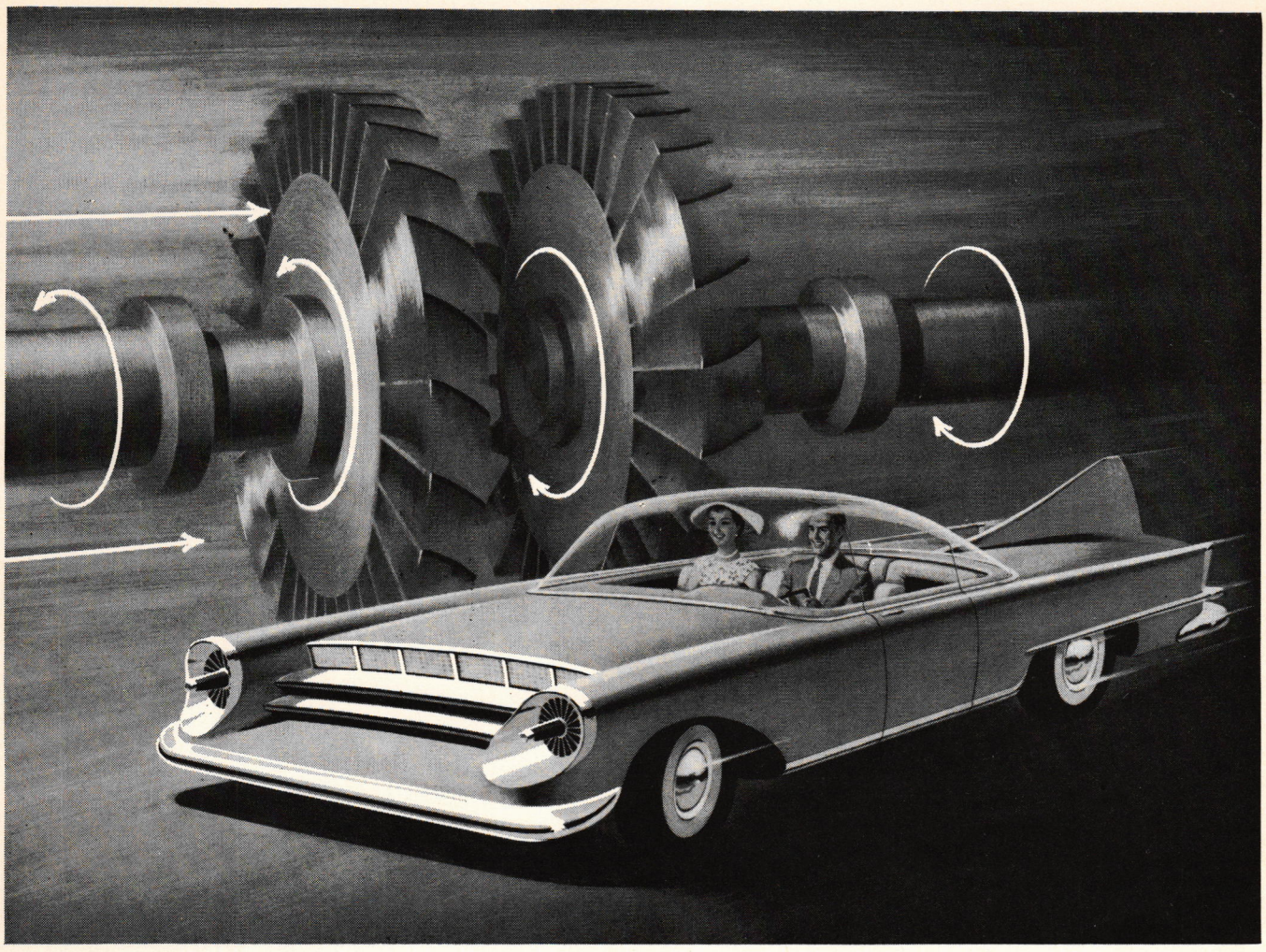
"b) At least 30 semester hours credit has been earned as a degree candidate in the School of Engineering.

"c) At least 15 (part-time student) or 30 (full-time student) semester hours credit in an engineering degree curriculum has been earned in the immediate two consecutive semesters.

"d) No grade below "C" has been received during the qualifying period stated in (c) above.

"e) No disciplinary action has been taken in respect to the student."

Beard, Richard M.
Bennett, Roland K.
Boardway, Robert A.
Calarco, John R.
Cutler, Edwin P.
Davis, Wayne A.
Denison, Lawrence M.
Eddins, Donald L.
Flatt, Harvey J.
Golab, Thomas J.
Gray, Charles M.
Grossman, Ronald A.
Hill, Howard T.
Horuichi, Harold S.
Jones, Horace T.
Lokerson, David T.
Mayo, Henry C.
Potterton, Richard L.
Santilli, Walter G.
Schuler, Bernard C.
Sibul, Leon H.
Thau, Stephen A.
Treynor, Paul E.
Whitesell, William A.
Wilkinson, Herbert S.



This "windmill" or turbine, spun by hot gas, powers the turbocar. For such a hot spot, designers depend on Nickel to help them solve heat-resistance problems.

How Inco Nickel is helping develop the new gas turbine car of tomorrow

It will be power-packed: the gas turbine engine in your dream car of the future and tomorrow's trucks and buses.

Only one spark plug—runs on kerosene

This new engine is much lighter, smaller. It has far fewer parts. No pistons. No water system. Only one spark plug. Runs on lower-grade fuels.

Not yet in production!

Before the car is a showroom reality, engineers face a number of problems.

One problem—the one Inco is helping with—is metals. Strong and economical metals to resist heat and corrosion.

Gas turbines operate at up to 1600°F. These temperatures step up corrosion of metals, promote troublesome distortions. So the job is to develop practical alloys able to carry the load—alloys that can, at the same time, offset the corrosives, resist the distorting forces found at jet-high temperatures.

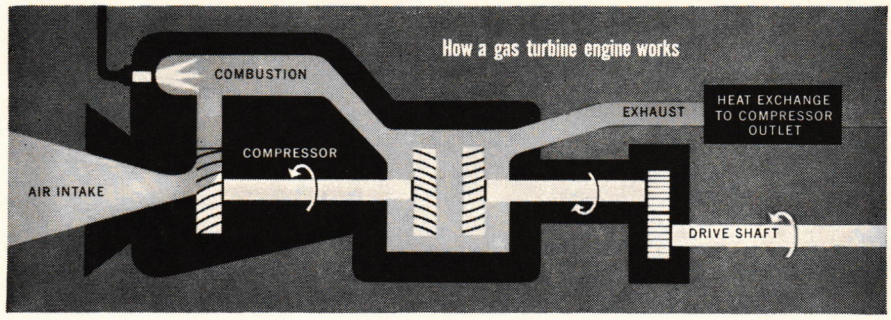
How far has Inco research gone in its search for practical alloys?

Difficult as they are, the problems of metal performance at high temperature are a familiar story at Inco. Inco research has dealt with them for years. And come up with solutions in the gas turbine and in many other fields. In conventional, atomic, and thermionic power. In petrochemistry. In heat treating. In jet aviation. In missilry. Even in Hollywood's 8000°F carbon-arc "suns."

Inco's files contain a wealth of metal information . . . over 300,000 indexed and cross-referenced case histories, for example. Keep this in mind against the day *you* may need information.

©1960, Inco

The International Nickel Company, Inc.
New York 5, N. Y.



INCO International Nickel

The International Nickel Company, Inc., is the U. S. affiliate of The International Nickel Company of Canada, Limited. Producer of Inco Nickel, Copper, Cobalt, Iron Ore, Tellurium, Selenium, Sulfur and Platinum, Palladium and Other Precious Metals.

Fundamentals of Underground Corrosion

by RICHARD BEUTTENMULLER, E.E. '60

The high cost of corrosion in the United States has been estimated previously to be some six or eight billion dollars per year. Accordingly, some estimates indicate that 70 to 75 thousand miles of pipe were buried for gas and oil products transmission in the last 15 to 20 years.

In this field of underground pipe line transportation we shall see tremendous activity during the next two decades. Estimates for the next 20 years indicate that the burying of 126,000 miles of gas transmission lines and 74,000 miles of oil and oil products lines are likely. To keep these pipe lines from corroding in service we must have competently trained intelligent men properly versed in the science of corrosion control.

It is with these thoughts that I present a paper on the Fundamentals of Underground Corrosion.

GALVANIC CELL

In 1792 Luigi Galvani reported on his experiments of dissimiliar metals in an electric circuit.

The principle of the electric cell discovered by Galvani is best illustrated by the operation of an ordinary flashlight battery (Fig. 1). In producing an electric current two dissimiliar metals, zinc and carbon, are suspended in an electrolyte and connected externally by a wire. In producing the electric current the battery case (zinc) corrodes. This corrosion is the result of current flowing from the zinc into the electrolyte.

Where current leaves a metallic surface (the anodic area) the metal will corrode. Where current flows onto the metal (the cathodic area) a film of hydrogen is deposited. This film of hydrogen acts as an insulator and tends to retard the flow of current.

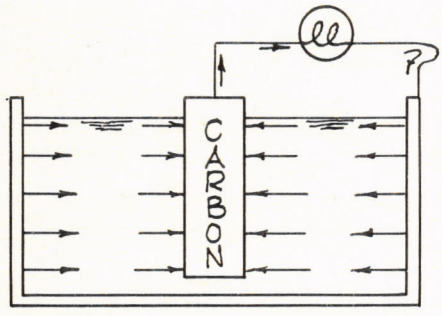


Figure 1

ELECTROMOTIVE SERIES

When two different metals serve as electrodes in a galvanic cell the metal higher in the Electromotive Series

Table 1. ELECTROMOTIVE SERIES

ELECTRODE	ELECTRIC POTENTIAL
Magnesium	−2.712 (anodic end)
Aluminum	−1.670
Zinc	−0.760
Iron	−0.440
Nickel	−0.250
Lead	−0.126
Hydrogen	0.000
Copper (divalent)	+0.345
Copper (monovalent)	+0.552
Silver	+0.800 (noble end)

will be anodic and will corrode; the other metal, the cathode, usually is not harmed. Also the further the metals are apart in the series the greater will be the voltage of the cell and the greater will be the corrosion tendency.

CORROSION CELL

In a corrosion cell there is an anodic area, an electrolyte, a cathode, and a return circuit. In addition we must have one or both of the following conditions: 1) The electrodes must be dissimiliar or, 2) the electrolyte must be dissimiliar at the two electrodes. We will examine these conditions more closely.

1. *Two dissimiliar electrodes.*

a) Two dissimiliar metals in contact.
When two metals widely seperated in the electromotive series serve as electrodes, they produce considerable voltage and corrosion can be rapid. An example is a brass shut off valve in a steel line (Fig. 2). The steel pipe is anodic to the brass valve and will corrode at the expense of protecting the brass valve. As a rule we do not like to join two metals together if they are a considerable distance apart in the electromotive series.

b) Different thermal treatment.
If two pieces of otherwise similiar steel are connected, but one is tempered and the other annealed, the tempered steel will be anodic to the annealed steel.

c) Differential strain.
A strained area is usually anodic to an unstrained area.

d) Scratches.
If a piece of metal is scratched or abraded, the scratched area will be anodic to the surrounding aera.

2. *Corrosion caused by dissimiliar electrolytes.*

a) Different composition of the electrolyte.
If a pipe line is run through a sandy loam and a short dis-

tance away the pipe is buried in a clay type soil, that portion of the pipe in contact with the clay will corrode. Galvanic cells caused by dissimilarily of soil may also be the result of mixing the dirt from the spoil bank when the ditch was dug.

b) Differential aeration.
In this case the soil throughout the depth of the ditch is uniform as to type or kind, but the pipe rests on heavy moist undisturbed ground at the bottom of the ditch, while the rest of the pipe is in contact with the drier loose backfill.

c) Temperature differential.
If the temperature of one area of a structure differs from another, the region of higher temperatures will be anodic to the cooler area.

d) Differential motion of the electrolyte.
If a structure is subjected to varying velocities of the electrolyte, the area of higher velocity will be anodic.

Several cases have been presented that can produce Galvanic Cells and, therefore, can cause corrosion. Although these represent the more important cases they are very few of the possible ones. Several of the combinations may exist at the same time and accelerate corrosion, or, fortunately, they may oppose each other and reduce or even eliminate corrosion.

STRAY CURRENT CORROSION

Many utility companies recognized as early as 1920 that in certain areas near the sub-stations of electric street railways, they could expect to have trouble with corrosion.

Most street railways operate with a single wire trolley, using the rails as the current return path to the electric generator. Networks of pipelines in the area of the trolley act as an additional return system by which current leaking off the rails returns to the sub-station (Fig. 3). Those sections where current is leaving the pipe line to take a path back to the generator are the areas in which severe corrosion takes place. Methods have been developed for reducing the extent of these areas by draining this "stray current" through necessary resistors and cables from the pipeline to the negative buss of the generator in the sub-station.

CATHODIC PROTECTION

In the above discussion we have explained the basic processes of corrosion. If it is possible to utilize these natural forces for our benefit, or perhaps nullify them, we might be able to prevent dangerous corrosion of underground structures.

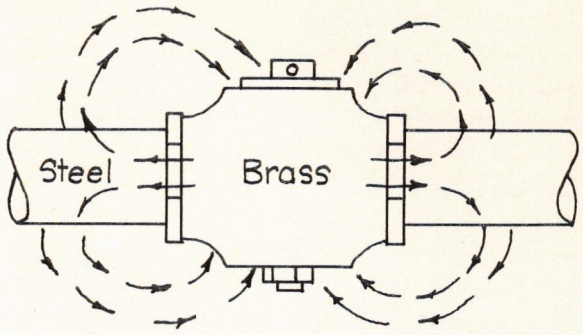


Figure 2

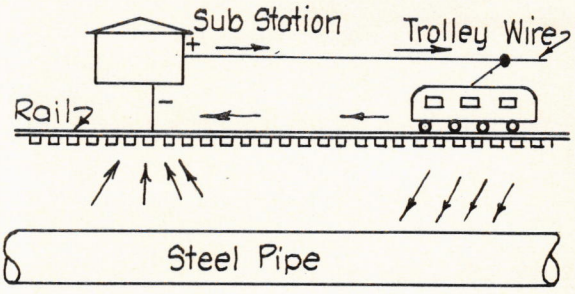


Figure 3

Basically, it is desired to make the entire structure cathodic. This was first tried by Sir Humphrey Davy in 1824, but nearly 100 years passed before cathodic protection came into general use.

SACRIFICIAL ANODES

One method used often is to supply an expendable dissimiliar metal to our structure so that a strong galvanic cell is created and thus it is possible to supress the natural anodic areas.

There are three readily available metals, aluminum, zinc, and magnesium, each of which will form a strong galvanic cell when combined with iron. Magnesium forms the strongest cell of the three and therefore is most used.

From Fig. 4 it can be seen that when magnesium is connected to a steel pipe, current will flow from the

Richard Beuttenmuller, M. E. '60, **comes to GW from New York City, where he attended high school and, on a scholarship program, earned a Bachelor of Science degree in Geology from City College of New York. After graduating from CCNY, Dick spent two years in the Army Corps of Engineers. While working in the Research and Development laboratory at Fort Belvoir, Dick decided that he wanted a degree in engineering. After leaving the Army in 1955, he began working full time at the Washington Gas Light Company (where he deals with underground corrosion every day), and attending night classes at GW. Young (born 1931) and energetic, he works full time, is married and has two children, belongs to Sigma Tau, the national honorary engineering fraternity, and is active in the student chapter of the American Society of Mechanical Engineers.**

magnesium to the surrounding ground (the electrolyte) taking metal ions of magnesium with it. The current flows through the ground onto the pipe, counteracting any undesirable natural galvanic cells present. The circuit is completed by welding a wire to the pipe and the magnesium for the return of the current flow.

The magnesium anode will corrode in providing this protection and enough must be installed to last for the period over which protection is desired. The anode installation pattern selected by the Corrosion Engineer will depend upon a number of factors, such as surface area of the underground structure, life expectancy of the anode, and whether or not the soil offers a large resistance to the flow of current.

One way to reduce the number of anode installations and at the same time increase anode life is to coat the structure with an electric insulating material such as asphalt, coal tar, plastic or grease. Any galvanic current flowing on a coated line will then be concentrated at any pin holes or breaks in the coating. By installing a magnesium anode and connecting it to the coated pipe it is possible to reverse any current flow leaving the structure through coating breaks.

RECTIFIER INSTALLATION

In many cases the cost of installing cathodic protection in the form of magnesium anodes becomes prohibitive due to one of the following reasons:

1) The structure is not coated and the number of anodes required for protection becomes excessive.
2) High resistivity soil limits the current flow from the anode.

When this happens it is a common practice to purchase alternating current from the power company, convert it to direct current by the means of a rectifier (Fig. 5). One side of the rectifier is connected to a ground bed of scrap iron or an abandoned structure. The other side is connected to the structure that requires protection. Current will then flow from the ground bed through the soil and onto the underground structure to be protected and will be drained off by the wire connected to the rectifier.

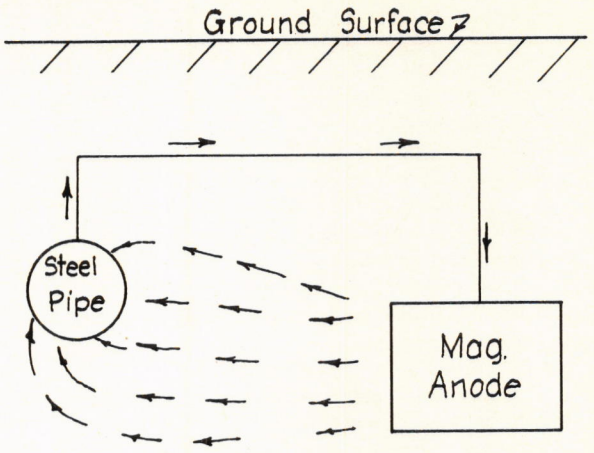


Figure 4

This method is simple and direct. But severe complications can occur by interference of foreign underground structures. These foreign structures may also pick up this impressed current from the ground bed and carry it along to some place near the power source where it will leave and then return to the negative side of the rectifier. A situation of this sort could prove to be embarrasing if the foreign structure is being used and is corroding at the expense of protecting yours. In practice this method of protecting underground structures becomes so complicated that its application should only be undertaken by an experienced Corrosion Engineer.

Conclusion

If engineers ignore these natural galvanic currents, corrosion will continue to destroy vital underground structures. If the engineer recognizes the natural laws of nature and utilizes them, galvanic currents can be put to work for the benefit of mankind.

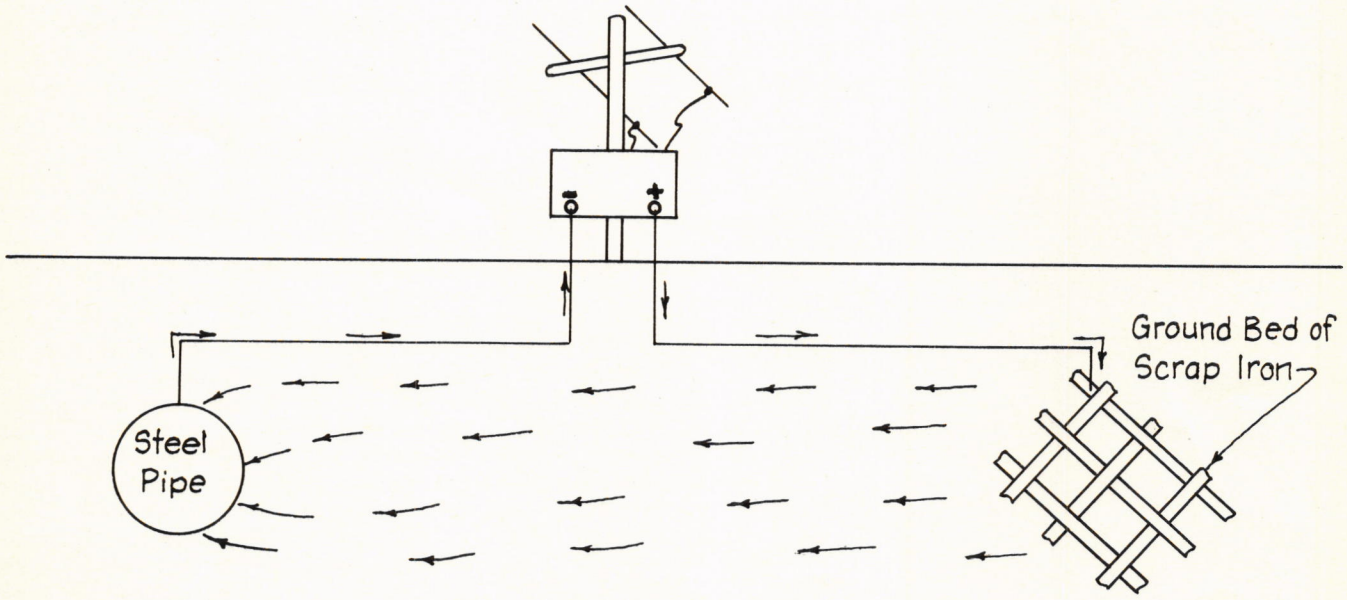
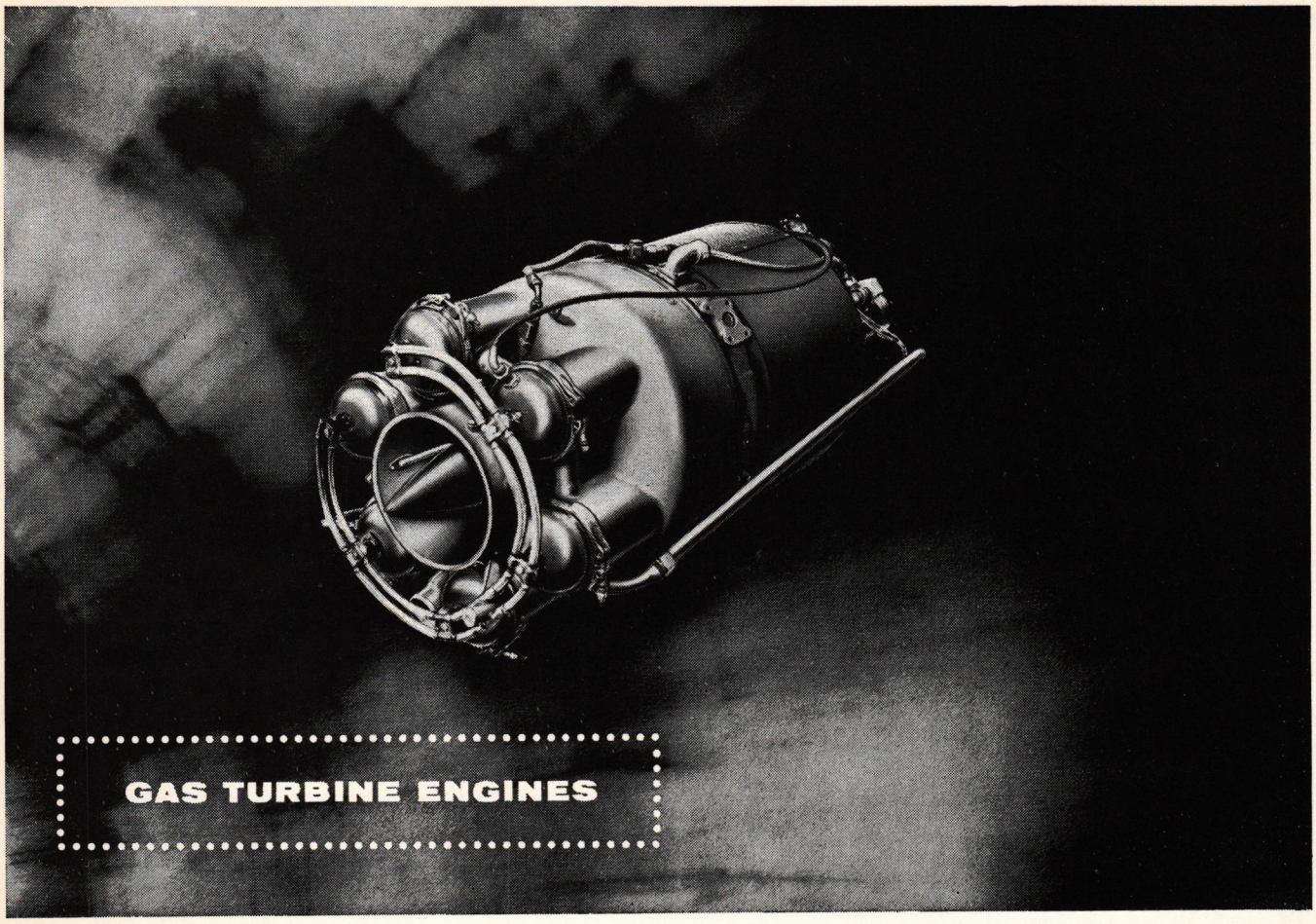


Figure 5



• The small gas turbine is an important aircraft support item used primarily for starting jet engines and providing on-board auxiliary power. The high compressed air and shaft outputs for its small size and weight mark it as an important power source for common commercial use. AiResearch is the largest producer of lightweight gas turbines, ranging from 30 H.P. to the 850 H.P. unit pictured above.

EXCITING FIELDS OF INTEREST FOR GRADUATE ENGINEERS

Diversity and strength in a company offer the engineer a key opportunity, for with broad knowledge and background your chances for responsibility and advancement are greater.

The Garrett Corporation, with its AiResearch Divisions, is rich in experience and reputation. Its diversification, which you will experience through an orientation program lasting over a period of months, allows you the best chance of finding your most profitable area of interest.

Other major fields of interest include:

• **Aircraft Flight and Electronic Systems**—pioneer and major supplier of centralized flight data systems and other electronic controls and instruments.

• **Missile Systems**—has delivered more accessory power units for missiles than any other company. AiResearch is also working with hydraulic and hot gas control systems for missile accessory power.

• **Environmental Control Systems**—pioneer, leading developer and supplier of aircraft and spacecraft air conditioning and pressurization systems.

Should you be interested in a career with The Garrett Corporation, see the magazine "The Garrett Corporation and Career Opportunities" at your College placement office. For further information write to Mr. Gerald D. Bradley...

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, NUCLEAR AND INDUSTRIAL APPLICATIONS

Proud of your School?

BE PROUD OF YOUR WORKING TOOLS...

A.W.FABER
CASTELL
helps the hand that shapes the future

#9000 CASTELL Pencil with world's finest natural graphite that tests out at more than 99% pure carbon. Exclusive microlette mills process this graphite into a drawing lead that lays down graphite-saturated, non-feathering lines of intense opacity. Extra strong to take needle-point sharpness without breaking or feathering. Smooth, 100% grit-free, consistently uniform, 8B to 10H.

#9800 SG LOCKTITE TEL-A-GRADE Holder, perfectly balanced, lightweight, with new no-slip functional grip. Relieves finger fatigue. Unique degree indicating device.

#9030 imported Refill Leads, matching exactly #9000 pencil in quality and grading, 7B to 10H, packed in reusable plastic tube with gold cap.

A man advancing in his career just naturally gravitates to CASTELL, world's finest drawing pencil. You'll be wise to begin now.

A.W.FABER - CASTELL
Pencil Co., Inc., Newark 3, N. J.

CASTELL 9030

Letters to The Editor

Comments and suggestions concerning Mechelecіv or any other phase of school activity are welcomed by the editor. Pertinent letters will be printed. Names will be withheld on request. However, names must be submitted with letters.

Dear Sir:

It has come to my attention that the library here at the university does not let undergraduate students into the stacks without special permission. This policy may be satisfactory for most students in the liberal arts courses, but for students in the scientific curricula, this causes a great hardship to anyone doing scientific research. The great number of textbooks in the scientific fields, many covering the same material, but in different ways, makes it imperative that the researcher look at many almost identical books to find the one with the information he seeks. I therefore propose that either Engineering students and students majoring in chemistry and physics be allowed in the stacks with a minimum of trouble, or that a scientific branch of the library be set up to hold only those books in the scientific catagories, and that the undergraduate as well as the graduate students in these curricula be allowed access to the stacks in this section of the library.

Why has the administration not set up this section, when the Engineers' Council at least has suggested it, and its need is obvious to even the most casual observer? Almost all of the large university libraries in this country have special sections for scientific books. It is high time that this University followed suit.

Yours Truly,
Studious.

Dear Sir:

I read with interest your editorial in the December issue, and was surprised that only one student wrote a letter commenting on it. I feel that this issue of examinations on material not covered in class, or not related to course matter is of great concern. If the United States is to remain ahead in the arms race with Russia, we must turn out well qualified men from the Engineering Schools of this country. These men should be used to their fullest capabilities. If some young student is discouraged by poor teaching or by unfair grading while enrolled in an Engineering School, he may well transfer into a different major, and be lost to this country's corps of engineers. This unpatriotic method of testing must be stopped at once, and the professors employing it should be investigated thoroughly for any taint of communist background. We must be ever vigilent.

Yours truly,
J. McCarthy
(ghost writer in the sky)

Dear Editor:

A *Norman B. Ames Educational Fund* is being established at the George Washington University in memory of Deacon Ames. I am sure you are aware of the help and counsel, whether it concerned scholastic or financial matters, the Deacon has given many students. It is proposed that an award be presented each year in the form of financial assistance to some deserving engineering student. Most students in the School of Engineering have experienced financial difficulty in one form or another and can, therefore, appreciate the worthiness of such an award.

We hope that all engineering students and alumni will contribute to this fund for the greater the financial assistance the more beneficial the award becomes. Please make all check payable to the *Norman B. Ames Educational Fund* and mail your contributions to:

John B. Pyle
4 Wyoming Court
Glen Echo Heights
Washington 16, D. C.

Thank you for your help and consideration.

JOHN ROBERTS
Theta Tau Fraternity

MECHELECIV

FEATURES

Technical

Humorous

Educational

Ridiculous

Profound

Malicious

Unintelligible

Scientific

Satirical

ARTICLES

DO YOU HAVE ANYTHING TO SAY? BRING IT TO US.

Seniors–Stay in touch with your alma mater.

Subscribe now to the MECHELECIV

Engineering Advances

Second of a Series

New and Useful Devices from the D-H Laboratories.

This month we present the second in a series of Engineering Advances, developed in the D-H laboratories somewhere in this area. Last month we presented the Galvanic Pornoscope, a remarkable device with extraordinary usefulness. Next month we intend to present something for the Electrical Engineers who seem to predominate in our enrollment here at GW. Since there are so many of you, we have spent extra time perfecting the electrical device which will appear on these pages next month.

This month's new idea is directed to those whose minds are really in the gutter, the sanitary engineers. These gentlemen, and I use the term loosely, are members of a specialized branch of Civil Engineers who work with those parts of society which are avoided by more normal people. The large increase in road travel occasioned by the completion of the Interstate system in the next few years will cause a great increase in demand for the services of the Sanitary Engineer in places rather sparsely inhabited. To alleviate his problem somewhat, the D-H Laboratory has come up with what it considers one of its greatest contributions to mankind. The pictured model, in the development stage, and therefore not operable, illustrates our point. The use of this invention is at once obvious. Telephone poles exist even in the most deserted areas, where gas stations are scarce, and the comforts of home scarcer. Now that we have given this invention to the public domain, we expect the Civil Engineers to spread the word around the world. Go to it boys.

STUDENTS

MECHELECIV *has several openings on next year's staff*

INTERESTING EDUCATIONAL

WRITERS

ADMINISTRATORS

MECH MISS CHOOSERS

Apply Now - - **MECHELECIV Office**

Davis-Hodgkins House

CORSON & GRUMAN CO.

PAVING CONTRACTORS

★

Asphalt and Concrete Pavements
Black Top Roadways
Tennis Courts

★

Office & Plant
33rd and K Streets, N. W.
Washington 7, D. C.

★

FEderal 3-3046

Washington's Tallest Building

Special Rates For Students

CAIRO HOTEL

1615 Que Street, N. W. • Washington 9, D. C.

LEE E. ADDELMAN
Manager

HObart 2-2104
Cable Address
"CAIROHOTEL"

PULSE GENERATOR

(Continued from Page 11)

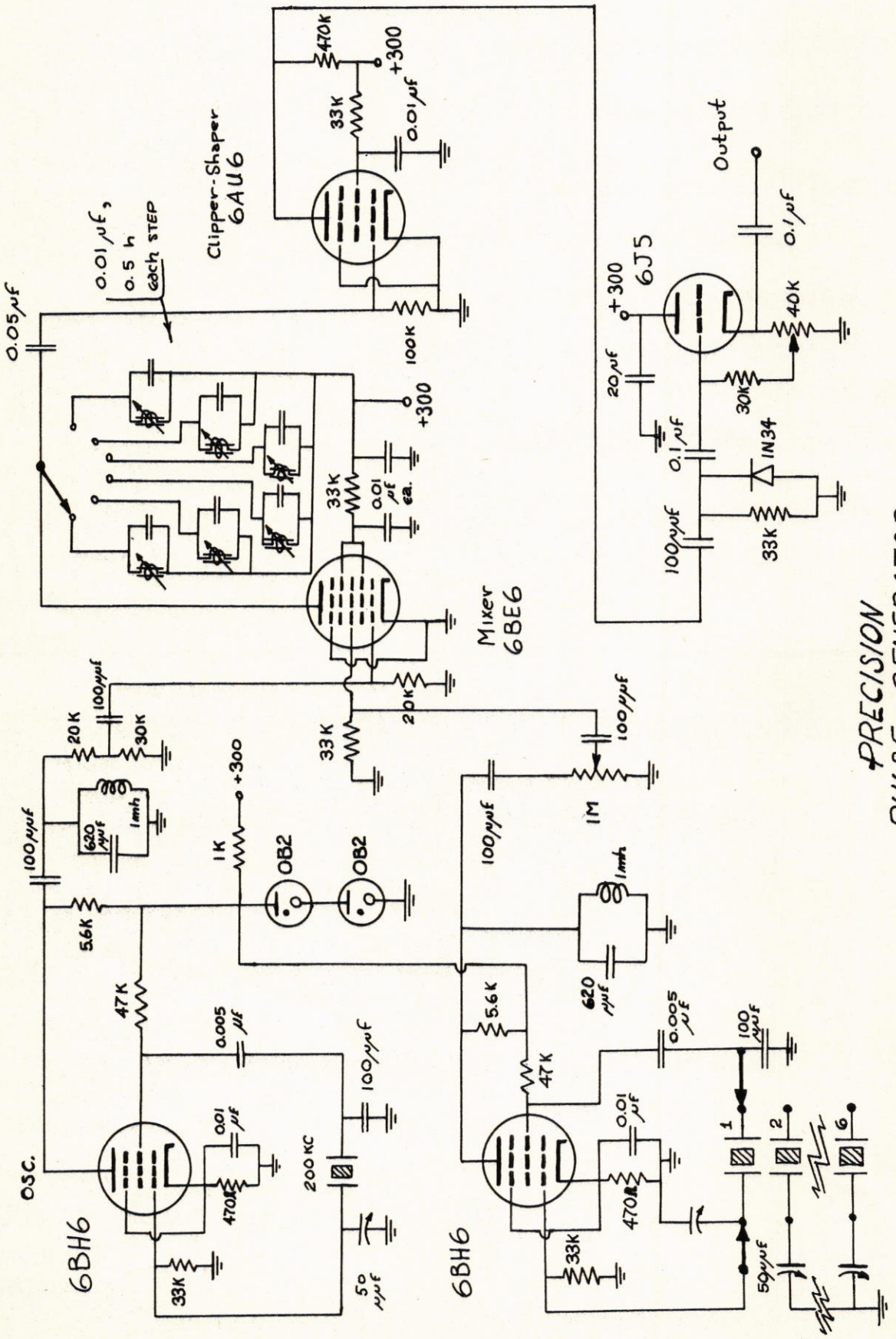


Figure 10—Schematic of the entire pulse generator.

The voltage levels for the 6AU6 shaper stage are as follows:

DC grid bias = −30 volts
6AU6 grid bias for plate current cutoff = −6 volts
6AU6 grid bias for plate current saturation = −½ volt

At the beginning of the input sine wave the tube is at cutoff. When the instantaneous value of the input voltage is 24 volts, the tube begins to conduct and amplify. When the amplitude is greater than 29½ volts, plate current saturation takes place, and there is no further amplification until the amplitude decreases again to below 29½ volts. Again the tube amplifies until the amplitude falls below 24 volts. At this point the tube cuts off and remains cutoff until the next cycle. If the negative slope of the sine wave is less than the positive slope of the sine wave, the tube conducts for a longer period of time when the amplitude is decreasing therefore the positive slope of the output wave is not as steep as the negative slope. See figure 8.

The output waveform was now ready to be differentiated. In order for an RC differentiator to work successfully, the time constant must be much smaller than the constant of 1 cycle of the input function. RC=1/1500 cycles=6.7×10^{-4} sec. The values chosen for the differentiator were R=33K and C=100 uuf. The time constant of this combination is 3.3×10^{-6} sec. This is much less than the time of one input cycle at 1500 cycles/sec.

After the differentiator was constructed, small positive pulses and large negative pulses were obtained. In order to eliminate the small positive pulses, a 1N34 germanium diode was paralleled to the output of the differentiator. The negative pulses were measured to be greater than 70 volts. Since the original requirement was for a minimum of 10 volts amplitude, no further pulse amplification was necessary.

Now that the proper waveform had been obtained, the unit had to have a low output impedance so that the pulses could be coupled into a low impedance line. Therefore, a cathode follower was chosen as a terminating circuit. For a 6J5, u = 20, and r_p = 7700 ohms.

A nominal forward voltage gain of 0.8 was picked. R_k was then obtained from the forward voltage gain equation.

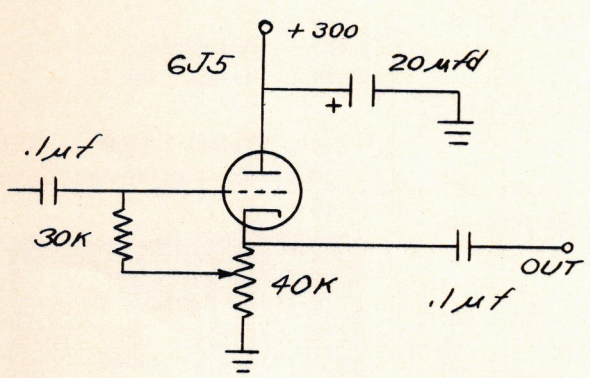


Figure 9

$$K_{VF} = \frac{\mu_u R_k}{(\mu + 1)\ (R_k + r_p)}\ ;\ 0.8 = \frac{20\ R_k}{(21)\ (R_k + 7700)}$$

$R_k = 44\ \Omega$

Since cutoff for the 6J5 is −5 volts, a provision had to be made to bias the tube properly as the input pulse swung negative. A standard method of accomplishing this is shown in figure 9. By varying the potentiometer setting the effective DC positive bias is shifted, causing the cutoff point to vary. The amplitude of the negative pulse varied, therefore, from 6 volts (potentiometer at ground) to 18 volts (potentiometer at the cathode).

The pulse width was measured on the scope to be 15 microseconds at 1500 cps; therefore, the pulse width requirement was also satisfied (see figure 5).

The completed pulse generator was taken to the David Taylor Model Basin where the unit was tested on a Beckman Electronic Counter. The generator was tested by allowing the generator to run for 3 hours and sampling the output count at 10-second intervals. It was found that the unit was stable to one part in 15,000 (99.993%).

The unit is now being used in conjunction with the Universal Computer Format Translator at the David Taylor Model Basin.

JANSKY & BAILEY, INC.

29 Years of

RADIO AND ELECTRONIC

ENGINEERING

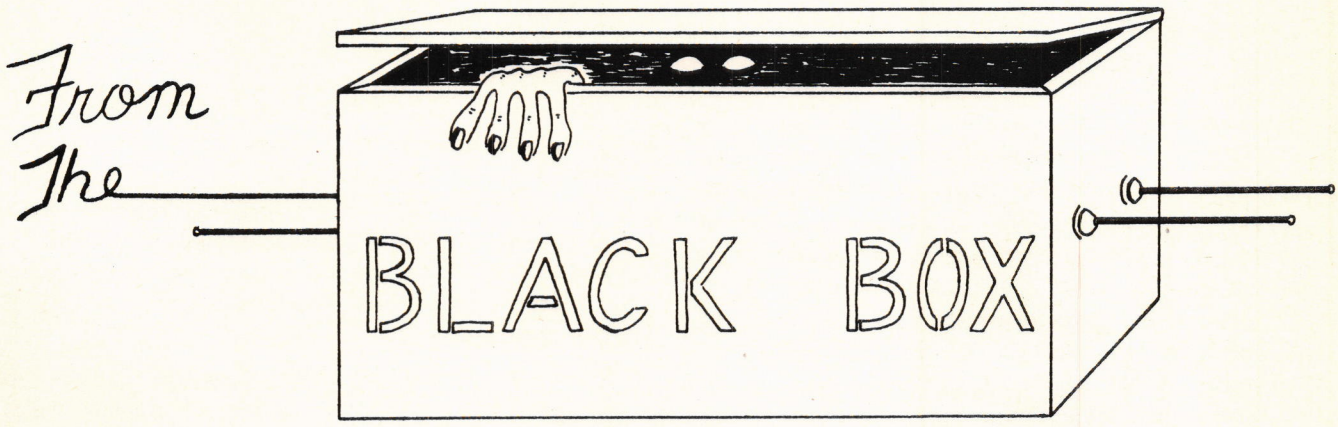
POSITIONS AVAILABLE IN THE FOLLOWING FIELDS

Antennas
Interference
Navigation
Propagation
Communications
Countermeasures
Broadcast and Television

Also Part-Time Training Programs For Second And Third Year Electrical Engineering Students

Contact:

Personnel Office, Engineering Building
1339 Wisconsin Avenue, N. W., Washington 7, D. C.
Telephone FEderal 3-4800



First Korean Vet: And there we were on top of that shell-torn hill fighting for our very lives. The odds were more than 200 to one.

Second Vet: Boy, that must have been rough.

First Vet: You said it! That was the meanest Chinaman we ever saw.

* * *

The apple of everyone's eye is the peach with the best pear.

* * *

Overheard at Brownley's the other night: "I hate to see a young girl like you ruin her reputation by hanging around a bar. Why don't you come on up to my apartment."

* * *

Conscience gets a lot of credit that belongs to cold feet.

* * *

A bright young professor named Bellow
Was a real "hep" collegiate fellow.
Smoked a new "cool cat" pipe,
Liked its savor so ripe.
Turned his breath and his teeth a bright yellow.

* * *

A lady buying tickets for her nine children explained to the ticket agent, "These three are all twelve years old and will take full fare; these three are all eight years old and will take half fare; and these three are all four years old and should go free."

The ticket agent looked at her in amazement and said, "Madam, do you mean that you have three every time you try?"

"Oh no," she replied, "lots of times we don't have any."

M. E.: I like mathematics when it isn't over my head.

E. E.: I feel the same way about pigeons.

* * *

And then there was the industrious engineering student who liked to make his Valentines.

* * *

Speakeasys in shady sectors,
Charleston, jazz, and hooch inspectors,
Ivy Leaguers, scandal, sin,
People drinking bathtub gin.
Scoins' money, all you ask,
Yellow roadster, pocket flask,
Yachts upon the Hudson tacking,
Women with their morals lacking,
Parties, fun, alas, alack,
When the hell's it coming back!

* * *

Neurotic: A relatively stable individual with both feet planted firmly in mid-air.

* * *

An engineer is a guy who is educated in the art of developing new and different ways of making the same mistake.

* * *

"I can't marry him, Mother, he's an atheist and doesn't believe there is a Hell."

"Marry him anyway, my dear, and between the two of us we'll convince him."

* * *

It was the sleepy time of the day. The Prof. droned on and on; formulea, constants, and figures. An engineering student, sitting in the back, was unable to restrain himself and gave a tremendous yawn. Unfortunately, as he stretched out his arms, he caught his neighbor squarely under the chin, knocking him to the floor. Horrified, he bent over the prostrate form just in time to hear a murmur, "Hit me again, Herb, I can still hear him!"

* * *

A man was accustomed to walking through a rural cemetery on his way home since it was a short cut. One night he started through, unaware that a new grave, seven feet deep, had been dug in his path. He tumbled into the grave. For almost an hour he struggled to get out but finally gave up and decided to settle down for the night.

A gangly farmer, out on a snark hunt, came walking through the cemetery. He, too, fell into the grave. He began a desperate attempt to get out, unaware there was anyone else in the grave.

The first man listened to him silently for a few minutes, and then reached over in the pitch darkness and laid a hand on his shoulder.

"You can't get out of here," he said.

A moment later he was alone.

* * *

"Carry your bag, sir?"
"Hell no, let her walk."

* * *

Happily Married Couple — Another man's wife out with another woman's husband.

DRAFTSMEN'S SUPPLIES
MUTH
1332 N.Y. Ave. N.W. ST. 3-6323
TRY MUTH FIRST

If your sights are set on electronics–

With the IBM Sage computer, Air Force personnel view computer-generated displays projected in the Command Post.

–you'll find **Photography at Work** with you

THE engineer working in electronics finds photography one of his most valuable tools. For example, he uses camera and film to capture and study the fleeting transient on the oscilloscope face.

X-rays and film provide him with a check on the internal integrity of sealed components. Even intricate circuits can be printed and miniaturized by photographic methods.

There's hardly a field on which you can set your sights where photography does not play a part in simplifying work and routine. It saves time and costs in research, on the production line, in the engineering and sales department, in the office.

So in whatever you plan to do, take full advantage of all the ways photography can help.

CAREERS WITH KODAK: With photography and photographic processes becoming increasingly important in the business and industry of tomorrow, there are new and challenging opportunities at Kodak in research, engineering, electronics, design, sales, and production.

If you are looking for such an interesting opportunity, write for information about careers with Kodak.

Address: Business and Technical Personnel Department, Eastman Kodak Company. Rochester 4, N.Y.

EASTMAN KODAK COMPANY
Rochester 4, N.Y.

Kodak
TRADEMARK

One of a series

Interview with
General Electric's Earl G. Abbott,
Manager—Sales Training

Technical Training Programs at General Electric

Q. Why does your company have training programs, Mr. Abbott?

A. Tomorrow's many positions of major responsibility will necessarily be filled by young men who have developed their potentials early in their careers. General Electric training programs simply help speed up this development process.

In addition, training programs provide graduates with the blocks of broad experience on which later success in a specialization can be built.

Furthermore, career opportunities and interests are brought into sharp focus after intensive working exposures to several fields. General Electric then gains the valuable contributions of men who have made early, well-considered decisions on career goals and who are confidently working toward those objectives.

Q. What kinds of technical training programs does your company conduct?

A. General Electric conducts a number of training programs. The G-E programs which attract the great majority of engineering graduates are Engineering and Science, Manufacturing, and Technical Marketing.

Q. How long does the Engineering and Science Program last?

A. That depends on which of several avenues you decide to take. Many graduates complete the training program during their first year with General Electric. Each Program member has three or four responsible work assignments at one or more of 61 different plant locations.

Some graduates elect to take the Advanced Engineering Program, supplementing their work assignments with challenging Company-conducted study courses which cover the application of engineering, science, and mathematics to industrial problems. If the Program member has an analytical bent coupled with a deep interest in mathematics and physics, he may continue through a second and third year of the Advanced Engineering Program.

Then there is the two-year Creative Engineering Program for those graduates who have completed their first-year assignments and who are interested in learning creative techniques for solving engineering problems.

Another avenue of training for the qualified graduate is the Honors Program, which enables a man to earn his Master's degree within three or four semesters at selected colleges and universities. The Company pays for his tuition and books, and his work schedule allows him to earn 75 percent of full salary while he is going to school. This program is similar to a research assistantship at a college or university.

Q. Just how will the Manufacturing Training Program help prepare me for a career in manufacturing?

A. The three-year Manufacturing Program consists of three orientation assignments and three development assignments in the areas of manufacturing engineering, quality control, materials management, plant engineering, and manufacturing operations. These assignments provide you with broad, fundamental manufacturing knowledge and with specialized knowledge in your particular field of interest.

The practical, on-the-job experience offered by this rotational program is supplemented by participation in a manufacturing studies curriculum covering all phases of manufacturing.

Q. What kind of training would I get on your Technical Marketing Program?

A. The one-year Technical Marketing Program is conducted for those graduates who want to use their engineering knowledge in dealing with customers. After completing orientation assignments in engineering, manufacturing, and marketing, the Program member may specialize in one of the four marketing areas: application engineering, headquarters marketing, sales engineering, or installation and service engineering.

In addition to on-the-job assignments, related courses of study help the Program member prepare for early assumption of major responsibility.

Q. How can I decide which training program I would like best, Mr. Abbott?

A. Well, selecting a training program is a decision which you alone can make. You made a similar decision when you selected your college major, and now you are focusing your interests only a little more sharply. The beauty of training programs is that they enable you to keep your career selection relatively broad until you have examined at first hand a number of specializations.

Furthermore, transfers from one General Electric training program to another are possible for the Program member whose interests clearly develop in one of the other fields.

Personalized Career Planning is General Electric's term for the selection, placement, and professional development of engineers and scientists. If you would like a Personalized Career Planning folder which describes in more detail the Company's training programs for technical graduates, write to Mr. Abbott at Section 959-13, General Electric Company, Schenectady 5, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC